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EXPERIMENTS

AND

OBSERVATIONS

ON

THE ATOMIC THEORY,

&c. &c.

EXPERIMENTS

AND

OBSERVATIONS

ON THE

Atomic Theory,

AND

ELECTRICAL PHENOMENA.

BY

WILLIAM HIGGINS, Esq.

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TO

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THE

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ERRATA.

PAGE LINE
15— 2 *from bottom, for* atoms *read* molecules.
24—13, *after* are *read* so.
45— 4, *for* rationalia *read* rationale.
69— 5, *for* molecule *read* molecules.
90—18, *for* examined *read* measured.
92—14, *after* measures *read* of sulphurous acid gas.
116— 7, *after* nitrous *read* gas, *and dele* gas *at the end of the next line.*
118—16, *for* simple state *read* uncombined state.
149— 9, *for* as it does on the metals *read* as the metals do.
—— *Note at foot of the page, for* Iroz. *read* Ros.

EXPERIMENTS

AND

OBSERVATIONS,

&c. &c.

IN the years 1787, 8, 9, 90, a very memorable and interesting controversy was maintained between the supporters of the phlogistic and anti-phlogistic doctrines. Lavoisier, the father of the anti-phlogistic doctrine, and a very few followers who were confined to France, considered most inflammable substances as simple bodies. The phlogistians, on the other hand, supposed them to consist of a certain base, and phlogiston, or an inflammable principle. The ancient phlogistians had no conception of the nature of their inflammable principle; but so soon as hydrogen was discovered, the modern phlogistians adopted it as the real phlogiston, and according to their doctrine this was the cause, by its intimate union, of the combustibility of all bodies that were capable of burning, or uniting to oxygen. Lavoisier insisted that oxygen united to metals, phosphorus, sulphur, charcoal, &c. from its attraction to them as simple bodies, and that the supposition of their containing hydrogen was erroneous.

He made many experiments to support his doctrine, one of which I shall mention as sufficient for the present. He confined mercury and oxygen, of ascertained weights, in an apparatus calculated for the purpose, and exposed the mercury to the heat of 700° of Fahrenheit: in time the whole of the oxygen united to the mercury, and converted it into a red oxide which weighed more than the mercury in its simple metallic state: this additional weight corresponded with the weight of the oxygen absorbed. When this oxide was exposed to a red heat, the whole of the oxygen was expelled in its gaseous state, without any change whatever, and the mercury was reduced to its metallic lustre and fluidity. This and many similar facts convinced Lavoisier that the agency of a third body, such as phlogiston, was fallacious and unnecessary, as the facts could be better explained without it.

The phlogistians denied these positions: they explained the process in the following manner. The oxygen united to the phlogiston and to the metallic basis conjointly, in a low degree of heat; and, in a higher degree, the oxygen was expelled, while the phlogiston was retained by the metal so as to recover its metallic lustre.* At this time the phlogistians would not allow water to be composed of oxygen and hydrogen. According to Dr. Priestley, the water produced, when those gases were united, was what they contained before their union or condensation, and that the compound which they formed was an acid.

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* In this way every phenomenon was explained with equal plausibility by both doctrines.

These circumstances led me to enquire, very minutely, and upon new principles, into both doctrines at this critical period, and the work which I published on the subject was entitled "A comparative view of the phlogistic and anti-phlogistic theories." The following quotation from the preface of that work will give a clear idea of the nature of the controversy.

"The present controversy between the philosophers of the day rests upon the following questions. 1st, Is water composed of oxygen and hydrogen? 2d, Does the union of oxygen to different bodies depend upon one inflammable principle, common to all combustible bodies? Or, in other words, do all bodies that burn or oxydate, such as charcoal, sulphur, phosphorus, metals, azote, &c. contain the matter of hydrogen as one of their constituent principles? One would suppose if these substances were composed of two elementary principles, namely, peculiar bases, and hydrogen in a solid state, that it would be no difficult matter to separate them, more especially when we consider the great attraction of the matter of hydrogen for caloric. Yet the phlogistians have not been able to accomplish this: Therefore the only ground they have to rest their hypothesis upon is, that these bodies unite to oxygen: according to this philosophy oxygen has the property of uniting but to one substance in nature, caloric excepted!

"If the above inflammable substances were simple elementary bodies, or even compounds free from hydrogen or phlogiston, the anti-phlogistians cannot do any more than what they have already done; for instance, suppose sulphur or charcoal were decomposed into two principles, either gases or solids, different in their nature from any other substances with which we are at present acquainted, the phlogistians might still insist that they contained phlogiston (hydrogen) if they even were the most simple bodies in nature, provided they possessed the property of uniting to oxygen.

"The anti-phlogistians, therefore, in order to establish the truth of their doctrine, have to prove the non-existence of a substance in bodies whose presence, as one of their constituents, has not hitherto been ascertained. On this difficulty the phlogistic theory seems to rest and to maintain itself.

"Thus seeing upon what principles the antagonist theorists maintained their different doctrines, in order to accomplish any thing decisive, I was obliged to have recourse to a mode of philosophising quite novel in the science of chemistry.* I have introduced several diagrams in order to render the nature of my investigations the more intelligible: I considered this the surest mode of reasoning, and the most effectual means of establishing truth and removing errors."

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* This alludes to the Atomic theory.

When I commenced my investigations of chemical theory, in 1788 and 1790, at which time the work was sent to the press, all the chemical philosophers of Great-Britain, Sweden, Germany, Ireland, Holland and Italy, and also most of those of France, were phlogistians. Under these circumstances, a very young man, such I was at that time, might well be supposed to be intimidated, and even deterred from offering an opinion on the subject of chemical philosophy; however the new views which I fortunately adopted furnished me with some degree of confidence.*

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* The following extract from a letter I received from Dr. Beddoes will shew the state of chemical theory at this period:—

"*Oxford*, 10*th of April*, 1789.

"Dear Sir,

.... I shall be glad to see your book, though I hope you have not taken Lavoisier's side of the question, or else have defended it by arguments totally unlike any thing that has yet appeared. Dr. Priestley's late admirable experiments have in my opinion totally overset that doctrine, and re-established the existence of phlogiston.

"Yours faithfully,

"THOS. BEDDOES."

I was very well aware of the importance as well as of the difficulty of the task which I proposed to myself. I had to frame a new system of investigation, in order to explore two doctrines that were, at the time, doubtful and abstruse.

I own it cost me many weeks, nay, many months of anxious meditation and study, before my plan was perfectly formed.

At length it occurred to me that chemical attraction only prevailed between the ultimate particles of simple elementary matter, and also between compound atoms.* The play of chemical affinities between those divisions were therefore only to be attended to.

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* In my "Comparative View" the term *ultimate particle* means the last division of elementary matter, and the term *molecule* the last division of a chemical compound. I now adopt for the latter the term *atom*, and for a more complicate compound that of *molecule*. This makes no difference in the system.

These considerations gave birth to that doctrine which Mr. Dalton, eighteen years after I had written, claimed as originating from his own inventive genius. What his pretensions are, will be seen from the sketches which will soon follow, and which have been taken from my book.

In the application of my system to chemical theory, I expressed by numbers the relative forces of attraction subsisting between the different kinds of ultimate particles and atoms of matter to each other. This was of infinite use to me during my researches, and if followed up would mature the science into that mathematical precision in which it is at present deficient.

This I consider as one of the most important features of the system: it has not even been mentioned by Mr. Dalton in his work, and when he repeats experiments formerly made by me, he does not even glance at the source from whence he derived his information.

I cannot with propriety or delicacy directly say that Mr. Dalton is a plagiarist, although appearances are against him. Probably he never read my book; yet it appears extraordinary that a person of Mr. Dalton's industry and learning should neglect one of the few works that were expressly written on the subject of theory. At the time it was published, there were one thousand copies of it sold, and it was the principal means of putting an end to the controversy already alluded to, which otherwise might not be determined for several years.

It is not my intention at present, whatever may happen hereafter, to correct my own errors, or to mend such as may fall to the lot of Mr. Dalton, except in a few instances where we differ in proportion, as to the constituent principles of certain compounds. My sole object is to claim what I conceive is, in justice, due to me.

Mr. Dalton has represented the ultimate particles of elementary matter by means of symbols, and atoms are represented in the same way with the proportion of their elementary constituents.

These signs correspond with my diagrams, except that numbers, expressive of the relative force of attraction, are left out. Those symbols, I own, shew some ingenuity: they are, excepting the omission of numbers, preferable to my diagrams. This can only be considered a mechanical improvement. Definite proportions are also represented by those symbols, and the same is strictly attended to by my diagrams. Specimens of both will be exhibited hereafter. The relative weights of the different particles of elementary matter, that of hydrogen being a standard, have also been given by Mr. Dalton. I have done the same in many instances. After this the relative weight of compound atoms could readily be conceived, and Mr. Dalton has extended this to saline substances. Here indeed many obstacles which have not as yet been removed, stand in the way: the principal one is, the great attraction of saline substances to water, which must interfere with the estimate deduced from the weight of their respective ultimate particles.

I will allow that the relative weight of the ultimate particles of metals might be inferred from the additional weight which they acquire by calcination, when the operation is performed by heat and exposure to air; but in order to this the degree of oxydation should be accurately ascertained.

Metals, like all the rest of the solid and fluid materials of the globe, consist of particles, which, when separated from each other, are invisible, indivisible, and unalterable in their size or shape, whatever that may be, as Sir Isaac Newton first observed. These ultimate divisions are held together by the aggregate attraction, and although apparently in complete contact, they are not so in reality; and probably in proportion to their diameters their distance from each other is very considerable. We have every reason to suppose that the ultimate particles of every substance in nature possess the same specific gravity, and that the difference in the weight of metals depends upon the distance of their respective ultimate particles from each other.* However this may be, no doubt the diameters of the particles of different bodies are not the same, and their weight is in proportion to their size. Every ultimate particle of a metal is surrounded with a small although dense atmosphere of caloric, together with a small portion of the electric or some other subtile fluid.†

When metals are presented under favourable circumstances to bodies that have a strong chemical affinity to their ultimate particles, those particles come into action independent of each other in the aggregate: they act as separate individuals, as has been demonstrated in many cases, in my Comp. View; for instance, when a metal, in a temperature sufficient to diminish its aggregate attraction, is exposed to oxygen gas, each particle will enter into union with one, two, or more particles of oxygen, according to the nature of the metal operated upon, for different metals unite with different doses of oxygen. If an ultimate particle of a metal is only capable of uniting but to a single ultimate particle of oxygen, the aggregate mass of the atoms of such oxide are unable to influence any more oxygen. This seems to be a general law throughout the whole system of chemistry; even when two atoms unite, the compound becomes surrounded with one common atmosphere of caloric, and rejects a third atom of either of its constituents. In short, there is a limit to the proportions in which the particles of elementary matter, as well as those of atoms, unite, which the old chemists expressed by the term saturation, and the modern ones by that of definite proportions. The former having no knowledge of the atomic system, could not extend their ideas on this subject beyond gross volumes.

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* This I have shewn to be the case in respect to some gases.—See pages 14, 15, of my Comparative View.

† See page 14, Comp. View.

It is not easy to ascertain when a metal is saturated with oxygen; for if that saturation should be limited by the union of an ultimate particle of the one with an ultimate particle of the other, so as to form a binary atom; metallic particles might be mixed with such an oxide; for the particle of oxygen cannot divide itself, it can only remain attached to one particle of metal.

Metals, whose particles are capable of uniting to two of oxygen, can have no metallic particles mixed with their oxides; yet it is possible to have them composed of ternary and binary atoms mechanically mixed, for the binary, in order to become ternary, cannot deprive the latter atom of any of its oxygen so as to leave it in a binary state.

A metal which unites to three portions of oxygen, may also have its oxide mixed in two different states of oxydation. It might consist of ternary and quaternary atoms. Binary atoms cannot exist in contact with the latter.

Those important chemical laws were first demonstrated in my Comparative View. (See pages 136, 137.)

From the foregoing considerations it is not an easy matter to ascertain when a metal is perfectly oxydated in the hands of the most experienced operator. Hence it is difficult to ascertain the relative weight of an ultimate particle of a metal, from the additional weight a given quantity of a metal acquires by oxydation. Besides, moisture is absorbed during the process of calcination, which must increase the difficulty. Yet it must be allowed to be the most effectual mode of any to approximate towards accuracy. I was the first who attempted to ascertain the relative weights of the ultimate particles of matter, as shall be proved hereafter.

The foregoing short statement will, I presume, prepare my reader for the evidences which will soon follow. I have read Mr. Dalton's "New System of Chemical Philosophy," as he calls it, with great attention; and also my "Comparative View," for the first time the last twenty years, and I cannot discover any improvement made in my doctrine, except what might reasonably be expected from any ingenious compiler, who had carefully perused my book. The nature of those improvements, such as they are, has been enumerated in the foregoing pages.

The atomic doctrine has been applied by me in abstruse and difficult researches. Its application by Mr. Dalton has been in a general and popular way, and it is from these circumstances alone that it gained the name of Dalton's Theory. Mr. Dalton's work is read; mine had been laid aside as soon as the controversy, which gave rise to it, ceased; and at that time the theory in question was not understood, nor did I expect it would for a considerable time. I calculated upon the middle of the present century. Probably it would have lain by since if it had not been for the genius and industry of Mr. Dalton.

As it is nearly five years since the first part of Mr. Dalton's "New System" appeared, it might be asked why I had not taken notice of it sooner; I will only say that it is with much reluctance I do so now at the request of some scientific friends. Besides, I had it in contemplation, for some years past, to publish a system of chemistry on a new arrangement, which I am now determined upon. In such a work I thought my claim to the *new system* would appear less pointed, and with more grace.

I have shewn in my Compar. View, that simple elementary particles, whether in a solid or gaseous state, governed a certain quantity of caloric which formed an atmosphere round them, somewhat similar in structure to the atmosphere which surrounds our globe; and also that probably the caloric was accompanied with a certain portion of electricity, as has been already alluded to.

Caloric, thus attached to the particles, comes under the denomination of specific heat, and is in all probability chemically united. We have every reason to suppose so, as it is as latent as an acid in sulphate of soda, or an alkali in nitre.

The ultimate particles of different kinds of matter, whether in a solid or gaseous state, do not retain the same quantity of caloric in their respective atmospheres. This probably is occasioned by their different forces of attraction to it. Those particles which attract caloric with most force, are surrounded with more of it, in a less space than those particles that attract it with a smaller force.

No doubt the aggregate attraction of the particles themselves, particularly in solids, diminishes the quantity of caloric which they otherwise would have influenced: this has been ascertained by various facts.

That substances, of the same degree of condensation and temperature, contain different quantities of caloric, has been proved: this had been attributed, long before the nature of the union of caloric to bodies was known, to their relative capacities for it, and the expression is still applicable.

When two ultimate particles unite chemically, their individuality is destroyed, and they form one solid atom whose capacity for caloric is less than its constituents in a detached or simple state;* hence it is that caloric is liberated by chemical union. These atoms however retain a sufficient quantity of caloric to furnish them with atmospheres.

When two atoms unite chemically, the compound molecule governs still less caloric than its constituent atoms, yet it is enveloped with an atmosphere.

Molecules of this kind are as distinct from each other, or as insulated in consequence of their respective atmospheres, as either ultimate particles or atoms.

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* I have adduced some exceptions to this general law in my Comp. View, in treating on the subject of nitrous acid, as shall be shewn hereafter.

Molecules set bounds to chemical combination, for here it almost invariably stops. Molecules of different kinds mix mechanically, or produce decomposition and new formations.

We may distinguish these different compounds from each other by the terms single and double compounds, and the latter, with few exceptions, contain less caloric than the former.

Many ingenious experiments have been made to ascertain the specific heat of bodies; that is, the whole quantity of caloric contained in a given weight or bulk of substances; yet I must own I have never felt convinced of the accuracy of their result, or rather of the inference deduced from them.

It is not my intention to enter here on so important a discussion which would require a whole volume to itself; my object at present, in addition to that already related, is to give a cursory view of chemical theories in general, but particularly of the atomic system.

It is impossible to deprive any substance of the whole of its caloric, although much of it may be extracted by means of artificial cold. The degree of cold that is capable of depriving an ultimate particle, or an atom, or molecule, of one tenth of their caloric, must probably require more than twice the degree of cold to separate two tenths, and so on progressively; for in proportion as caloric is taken away, what remains is retained with the greater force. This law has been demonstrated in my Comparative View, (See page 41.) In short, this doctrine prevails throughout the whole of that work, and in many instances it has been there expressed by numbers. I do not intimate that this doctrine related to caloric: I confined myself to the atoms and ultimate particles of ponderable matter: the same law however holds equally good in either case.

The idea that ultimate particles of matter, which are so exceedingly minute that the molecule itself, which consists of many of them, is invisible, even by the help of microscopes, should be surrounded with an atmosphere of caloric, might appear too hypothetical and fanciful to many. What are the planets in our system, which we consider worlds, but small molecules in comparison to the immense space in which they move? They are all surrounded with some kind of matter, and probably this matter, whatever it may be, in a great measure prevents their coming into contact, at the same time that it presses them towards each other. Might not the projectile and rotatory motion of the planets be produced and preserved by the unceasing action of this subtile matter? Had Sir Isaac Newton been perfectly acquainted with the laws of electricity and caloric, at the time he had written his Principia, very likely his philosophy would have taken a different turn.

Our own planet is surrounded with an atmosphere, but the materials of which it consists are terrestrial, for oxygen constitutes a great part of the solid masses of our globe, such as the earths and water (ice); and azote also exists in a solid state, united to certain bodies. Our globe and that atmosphere may be encircled with a still more subtile fluid, so as to form an atmosphere that extends to the confines of that of its neighbouring planets.

The ultimate particles of ponderable matter are exceedingly minute, but those of imponderable elements, such as caloric, electricity, and light, are beyond calculation. The utmost stretch of the human mind can no more estimate the size of those particles than it can measure space and duration. However, their divisibility is limited.

Probably a single ultimate particle of caloric bears the same proportion, in its size and weight, to a particle of oxygen, as the latter does to our globe: hence arises the impossibility of ascertaining the weight of that element.

From the foregoing considerations we can readily conceive the nature and structure of the calorific atmospheres which are influenced by particles, atoms, or molecules, of ponderable matter.

The quantity of caloric in gases is very considerable, particularly in those which are uncompounded.

Solids also contain a prodigious quantity of caloric, as may be shewn by deflagrating together nitre, brimstone, and crude antimony, reduced to powder, and intimately mixed. The intensity of the heat, and brilliancy of the light, produced in this way, are dazzling to the sight. The greater part of this caloric exists in the nitre. If the quantity of caloric contained in any solid substance were accumulated upon another of the same bulk and temperature, the heat produced would be very great; for instance, if the caloric of ice were transferred to the same bulk of cast iron, it would be more than sufficient to effect its fusion.

There are only three ways of setting free any quantity of specific heat contained in bodies: the first is by chemical action; the second, by pressure on gases, or by hammering malleable metals so as to approximate their ultimate particles. The third, and last, is accomplished by means of electricity in the state of a certain degree of accumulation and density. This I only offer as a mere hypothesis, for the present, although well-known facts tend to support my opinion.

By strong electric sparks gunpowder and alkohol are inflamed. This inflammation is occasioned by caloric which is disengaged from these substances, or from the air in contact with them. Small metallic wires are also ignited and fused by a strong electric battery; and it frequently happens that by the same means silver and gold wires are dissipated into very minute divisions and converted into oxides. This I conceive to arise from a rapid dislodgment of the specific heat of the metals by the electric matter. Upon a similar principle it is, that small wires of platina, copper, iron, &c. are ignited or fused by a strong voltaic battery, particularly that composed of broad plates.* When a platina wire, sufficiently thick to resist fusion, is used, the glow of heat and light produced is exceedingly bright. The same effect is produced when charcoal is made use of. These brilliant phenomena are effected by the specific caloric of those substances, which is disengaged in a free state from their particles by the superior influence of the electric matter which occupies its place during its presence. These phenomena are produced in vacuo with equal brilliancy as in oxygen gas.

As the heat thus produced will continue while the battery acts with sufficient energy, and as there must be a constant waste of the specific heat of both the charcoal and metallic wires, this doctrine may appear defective. If it be allowed that the electric fluid is capable of disengaging specific heat on the principles which have been adduced, it must also possess the power of urging on, during its passage, through the battery and conductors, a sufficiency of caloric to supply the waste occasioned by the ignition.

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* The order of the fusibility of metals by exposure to heat in the common way, is somewhat reversed when the electric fluid is made the medium of fusion. This circumstance is favourable to my hypothesis, for in this latter case their fusibility depends upon the quantity of specific caloric which they respectively contain.

When oxygen and hydrogen are mixed, their ultimate particles, notwithstanding their chemical attraction to each other, will not unite. This kind of neutrality does not proceed from the distance at which they are held by their caloric, but from the structure of the atmospheres which it forms round them, and which tend to preserve and press to their respective centres their gravitating particles.

When an electric spark is passed in this mixture of gases, it liberates the specific heat of that part which it meets in its passage from one conductor to the other; thus the atmospheres being destroyed, the gravitating particles unite, as meeting no resistance in a medium of uniform density: the caloric of that part of the gases condensed by means of the electric fluid produces a similar effect upon the atmospheres of the other part of the mixture. This is effected with a velocity almost equal to the passage of the electric spark. The same effect is produced by a flint spark upon the same principle, that of *blending* the atmospheres. Doctor Higgins was the first who advanced this ingenious doctrine in his excellent Treatise on Acetous Acid, a work which is shamefully passed over by modern writers on that subject, although his book was published when the nature of that acid, so far as related to its internal structure or constituents, was unknown to others. Dr. Higgins's idea of the *modus operandi* of the electric matter and mine are quite different, even in this experiment.

When a strong electric spark is passed in oxygen gas, or any other gas, a flash of light is produced: this is occasioned by the liberation of a portion of the specific heat, which resumes its former station as soon as the influence of the electric matter is removed, which is instantaneous.

The explosions produced on such occasions are the effects of expansion by the liberated caloric and instantaneous absorption of it again by the particles of the gas, by which means the gas becomes condensed to its original dimensions.

The same effect is produced on the large scale of nature. When the electricity of a cloud passes to another cloud in a negative state, or to the earth, or from the earth to a cloud, a portion of the specific heat of the intermediate air, in the direct line of its passage, is set at liberty for a moment. This is the cause of thunder and lightning. When this operation takes place at a distance, we perceive the flash of light before we hear the thunder, in consequence of the greater velocity of light than that of sound.

The effects of lightning in destroying edifices, fusing metals, setting fire to inflammable bodies, and depriving animals of life, are explicable on the foregoing principles.

The brilliant phenomena of the aurora borealis, in the upper regions of the atmosphere, are effected by electricity in the same manner.

By the help of this theory we are enabled to account for those fiery meteors which occur so frequently in our atmosphere.

Those meteors move with great velocity, partly in an horizontal direction, but approaching gradually towards the earth. When they reach within a certain distance of it, the phenomena of thunder and lightning are produced; and at that moment they come down most frequently shattered into small masses with the effect of fusion on their surface, although their internal parts are quite free from any appearance of that kind.

From the analyses of these stones, it appears that they consist of iron in its metallic state, without any determinate form, small portions of nickel, oxide of iron, and sulphur.

The stone which fell in the county of Tipperary, a few years ago, was found by my analysis to consist of the same ingredients with others which had fallen on different parts of the globe, according to the analysis of Mr. Howard.

As those stones are different from any mineral substance hitherto discovered on our globe, we must consider them as foreigners. It is supposed by some that they never belonged to any planet, and that they were opaque wandering masses before they reached the confines of our atmosphere. This, certainly, is the most rational mode of accounting for their existence in the situation in which we first behold them.

However, my principal object is to account for their luminous appearance.

Those masses contain specific heat round their particles, like other bodies of similar nature. In moving through the atmosphere they collect electricity, and this continues increasing, as there is no other solid matter in those upper regions to prevent its accumulation. When they acquire a sufficient quantity of electric matter, a portion of their specific heat is liberated and thrown upon their surface: this gives the luminous appearance. As they are of an inflammable nature, a portion of oxygen unites to their external parts. The degree of heat occasioned by these different circumstances will account for that superficial fused crust with which they are found invariably to be surrounded.

Those electric stones, in descending towards the earth, when they meet with a cloud comparatively negative, lose their electricity, which, bursting forward with great vehemence, exhibits the phenomena of thunder and lightning: at the same time they are most commonly shattered into pieces. So soon as this takes place, their luminous appearance ceases, and they are precipitated to the earth, still retaining a considerable degree of heat. The stone that fell in the county of Tipperary could not be touched with the hand for some time after its descent.

Thunder and lightning accompany volcanic eruptions; particularly at their commencement. Although the electric matter alone is not sufficient to produce all the effects, yet it might be the primary cause. During the interval of volcanic eruptions, the electric fluid is gradually accumulating on the inflammable materials (pyrites) and other substances which constitute the subterraneous strata whence the eruption issues; and when collected in a sufficient degree of concentration and density, specific heat is liberated; this heat produces the chemical action of all the elementary principles in the whole mass. By these means a considerable degree of heat is produced, gases are formed, and fixed substances are fused. The heat continues to increase, as there is nothing to carry it off, until the eruption takes place, which is occasioned by the expansive force of red hot gases that burst a passage in the direction in which they meet with the least resistance, that is, to the surface of the earth. The liquid part, or lava, is also forced to the surface upon mechanical principles so obvious that I need not dwell on them at present.

Violent earthquakes are also accompanied with thunder and lightning at their immediate source: hence we are induced to attribute those convulsions of nature to the force of subterraneous electricity, on the same principle that concussions are produced in our atmosphere by the same element.

The heat produced by friction, although it constantly takes place under various circumstances before our eyes, has not hitherto been accounted for upon any rational principle. It cannot be attributed to an union with oxygen gas, or to any chemical action of ponderable particles, as had been shewn by Count Rumford.

This philosopher, being struck by the heat evolved by the friction of bodies, took a solid cylinder of iron, near 8 inches in diameter, and 9,8 inches long. In this cylinder a hole was bored 3,7 inches in diameter, and 7,2 inches in length. A blunt steel borer was introduced into this hole, which by means of horses was made to rub against its bottom with a considerable weight. The cylinder was wrapt round with flannel to keep in the heat, and it was turned round at the rate of 32 times in a minute. At the beginning of the experiment the temperature of the cylinder was 60°; at the end of thirty minutes, when it had made 960 revolutions, its temperature was 130°.

To prove that the caloric produced was not occasioned by the union of oxygen, Count Rumford enclosed the cylinder and borer in a wooden box filled with water so as to exclude the air. The quantity of water was 18,77 pints, and at the beginning of the experiment it stood at the temperature of 60°. After the cylinder revolved two hours and thirty minutes, with the velocity already described, the water boiled.

Whether the water was excluded, or allowed free access into the hole in the cylinder where the friction took place, the result of the experiment was the same.

Mr. Pictet, of Geneva, made some experiments on the friction of bodies in air, and in vacuo, without any difference as to effect.

These facts led the above philosophers to suspect, that heat, like gravity, might be a mere property of common matter, and that it is produced by a peculiar vibration of their particles, more especially as there appeared no perceptible source from which, as a substance, it could possibly be derived.

Heat evolved by friction, however unaccountable and mysterious it may appear, is not sufficient to invalidate the doctrine of the materiality of caloric, being only a solitary fact opposed to thousands that tend to establish its existence as an elementary substance.

When bodies unite chemically caloric is given out: can this be effected by vibratory motion of the particles? Were this the case, heat ought to be evolved during the solution of saline substances in water and acids, whereas cold is produced. The motion of the particles or atoms is the same in both cases. When a bell is rung, all its particles are made to vibrate strongly, yet no heat is produced by ever so long a continuance of those vibrations. Should heat be produced by vibration of the particles of ponderable matter, it ought to disappear the instant such motion ceases, which is not the case.

What keeps the particles of gases in solution, or at such a distance from each other? It must be attributed to the caloric given out so copiously during their chemical union.

In my humble opinion the heat produced by friction can only be accounted for on those principles which I have already adduced.

Friction invariably excites and accumulates electric matter on the bodies rubbed: if they are good conductors, it circulates very quickly through them, and the quantity of the electric matter thus induced in a given time, is in proportion to the rapidity of the friction. Upon what principle this effect is produced, is totally unknown at present, although the fact is fully established, particularly by the operation of an electric machine.

Might not the heat produced in Count Rumford's experiment, arise from a dislodgment of a portion of the specific heat of the iron through the influence of electricity, which must flow in every direction to the centre of friction? And might it not also, in its passage thither, force on before it another portion of heat from the calorific atmospheres which it meets?

We have every reason to suppose that the particles of imponderable elements, like those of the ponderable, have their different forces of attraction to bodies.

The de-oxydizing rays which accompany those of light, separate ponderable elements, such as oxygen and metals, and oxygen and hydrogen, and oxygen and carbon. This elementary substance must therefore be inimical to the process of combustion: we should therefore be the less surprised at finding one imponderable element to disengage another imponderable element from its chemical union.

Caloric and the electric fluid are antagonist elements, whereas light and caloric seem to be kind and almost constant associates. The light of the sun, and that produced by artificial means, are accompanied by caloric.

Moon-light seems to be quite free from caloric, which on that account might appear an exception to the foregoing law: but we are to consider that this kind of light is reflected from a considerable distance, and from a great body that might retain the caloric that accompanies it from the sun, or reflect it back again to that luminary.

Electricity, in its pure simple state, is incapable of producing heat or light. When a Leyden jar is overcharged with the electric fluid, rays of light diverge from between the wooden cover and the edge of the glass: this light is so feeble, it is only visible in the dark; but when the whole charge of the jar is made to pass in air at one sudden explosion, a very vivid flash of light is produced: when passed in air rarefied by partial exhaustion, by means of an air pump, the light is less vivid, and continues diminishing in proportion to the rarefaction, because in this state it meets with less caloric in its passage.

When the air is completely removed, which can only be effected by the Torricellian vacuum, it not only passes with some difficulty in such a medium, but neither light nor heat is produced. Philosophers do not agree as to this fact, which must be in consequence of the great difficulty of producing a perfect vacuum.

Substances that retain the calorific atmospheres of their particles or atoms with the greatest force, are the worst conductors; because the electric fluid has to force its way by removing a certain portion of caloric which obstructs its passage. The quantity of caloric thus liberated depends upon that of the electric fluid, and the effects it produces as free caloric, are more or less sensible according to the thickness of the conductor. For instance, the electricity of a large cloud will melt a mass of metal, whereas that of an electric or voltaic battery will only fuse small wires.

Metals, charcoal, and living animals, are the best conductors of electricity, as a sufficient portion of their caloric is readily removed on its passage through those substances.

Dry oxides are non-conductors, as their calorific atmospheres are small and strongly attached to their atoms. Glass also, which consists of different oxides fused in one solid mass, is a non-conductor on the same principle, and so are resinous substances; yet glass and resins become good conductors when sufficiently heated so as to enlarge their calorific atmospheres.

The liquid oxides, namely, acids and water, are bad conductors of electricity, and, when it passes through them, a portion of their specific heat is removed for a moment. The same effect is produced in dry gases, which are also bad conductors, partly upon the foregoing principles.

We know very little, at present, of the internal nature of the imponderable elements. Although we are acquainted with many of the phenomena which they produce, yet the greater part of the duty allotted to each is veiled from our senses: every one of them has to perform an important office in the system of nature, not excepting the great scale of our planetary system. In our own little world (the earth) every thing is performed by them; animalization, vegetation, life, and motion, are their attributes, for in their absence the ponderable materials of our globe would be one chaotic inanimate mass, or, in the language of the old chemists, a *caput mortuum*. We must therefore consider them as agents in the hands of Providence to effect his all-wise and mighty purposes.

We shall never be perfectly acquainted with the laws of nature while we are ignorant of the properties and operations of those subtile elements that guide, animate, and move the whole of the universe.

Our ancestors, so late as sixty years ago, were as unacquainted with the nature of atmospheric air as we are at present with that of the imponderable elements. They considered it beyond the reach of human investigation, having no conception of the implements and apparatus calculated for such an intricate inquiry.

We are nearly in the same situation, as to the imponderable elements; we possess very imperfect means of examining them, consequently the rationalia of their most important functions are concealed. However, I entertain hopes that at some future period posterity will gain that power over them which we now possess in the extensive field of pneumatic chemistry.

The theory, or rather the hypothesis, which I have advanced, on electrical phenomena, is founded on well-known facts, and according to my knowledge is quite new. It is simple and uniform in its application, and capable of accounting for many phenomena which appeared hitherto inexplicable upon any rational principle whatever. Should it stand the test of further investigation, it will establish the materiality of the imponderable elements beyond a shadow of doubt.

So fully convinced am I, at present, of the truth of this doctrine, that no vague or superficial objections will be able to stagger my creed: at the same time I am ready to submit to convincing facts and arguments, for truth should be the sole object of every writer on philosophical subjects.

I will now return to the atomic theory, the principal object of this essay, and endeavour to submit to the philosophical world such testimony as will enable it to judge who is the author of that doctrine.

When I had written, the present chemical nomenclature was not adopted: azotic gas was then called phlogisticated air; oxygen gas, dephlogisticated air; hydrogen gas, light inflammable air; and caloric was distinguished by the name of fire; and so on, as to other substances. Modernising, therefore, that part of my book which must necessarily be transcribed, cannot be considered misrepresentation. In many instances, it will be necessary to render passages shorter and more perspicuous than they are in the original, particularly as this doctrine was applied to abstruse investigation, as I have already mentioned. There shall be no alteration whatever, as to the mere matter of fact; and reference will regularly be made to the pages of the old work. Any additional remarks that are made, will be in italics, or in a note at the foot of the page.

Although the theory in question runs throughout the whole work, consisting of 280 pages, I will only trouble the reader with certain passages, which circumstance must unavoidably mutilate the system which I advanced. It will, however, answer the purpose of ascertaining whether any and what part of this doctrine originated with Mr. Dalton.

It is almost unnecessary to quote any part of Mr. Dalton's work, it being so well known, and so recently published; yet I shall transcribe those passages at the end of this treatise that he or his friends would have adduced, were they to contest the present question. I shall also present specimens of his symbols and his ingenious method of exhibiting, by their means, the constituents and proportions of atoms and molecules.

I consider his definite proportions and weight of atoms in many instances very erroneous, as shall be proved in the course of this work. The few experiments he made were not sufficiently accurate to justify his conclusions. But let facts answer for themselves.

Mr. Kirwan was the first who opposed the theory of Lavoisier, in a treatise written expressly for the purpose, called "Essay on Phlogiston." One of his first objections was to the table of Lavoisier on the affinities of the oxygenous principle to different bodies, wherein he placed charcoal above iron.

Mr. Kirwan supposed that charcoal, according to the precedency given it in this table, should decompose water in a boiling heat, at least, (*which is not the case*) considering that iron, which is placed lower, will produce hydrogen under the same circumstances.

The reply which I made to Mr. Kirwan, on this subject, will exhibit the first dawn of the atomic theory ; and the series of chemical affinities adduced on the occasion, as being still problematical, deserves the attention of modern philosophers. It is as follows:*

"The nature of charcoal should be first considered. Although the aggregate attraction of its parts appears weaker than that of iron, from its facility of pulverization; yet, when reduced to powder, or small molecules, its ultimate particles may cohere with greater force.

"The frangibility of charcoal is in a great measure owing to the number of minute cavities which intersect its texture; from the expulsion of hydrogen, and the succulent part of the wood.

"Independent of the aggregate attraction which counteracts chemical union more than we are aware of, it appears to me that the ultimate particles of charcoal are surrounded with some repelling fluid which defends them from the action of air and water. The same may be said with respect to alkohol, oil, and ether; for they all have greater attraction to oxygen than phosphorus has, which unites with it in the common temperature of the atmosphere.* Whether this be occasioned by caloric, the electric fluid, or some other subtile fluid, with which we are unacquainted, deserves attention.

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* Comp. View, p. 11.

" Nitrous air will rush into union with oxygen gas, in any moderate temperature, yet sugar will not do so, although it will deprive the nitrous air of its condensed oxygen.

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* This holds good when phosphorus is exposed to atmospheric air. When dry phosphorus is confined over mercury in perfectly dry oxygen gas, no union will take place in a common temperature, so that the slow combination of phosphorus is promoted by the azote, which acts on it as a solvent.

"Pure calcareous earth (lime) will have no effect on muriatic gas, when both are perfectly dry; yet water, to which this gas has no chemical affinity, will condense it: in this state it will readily form an intimate union with the lime.

"Oxygen and hydrogen gases, when mixed in their simple state, will not unite, notwithstanding their chemical attraction for each other, unless exposed to an electric or a common spark, yet they will readily combine when one or both are partially condensed; instance, nitrous air, which, as will hereafter appear, consists of oxygen and azote, will condense hepatic gas.* Hepatic gas, as shall be shewn, is hydrogen in its full extent, holding sulphur in solution. When those gases are mixed, sulphur is deposited, and the residuary air is found to be the gaseous oxide of azote.† In this experiment a portion of the oxygen of the nitrous air unites to the hydrogen of the hepatic gas, and forms water. It does not appear that this takes place in consequence of a double affinity.

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* Comp. View, pages 12, 13.

† At the time the above was first written, nitrous air was considered by many chemists a compound of nitric acid and phlogiston.

"Azotic gas is made to unite with great difficulty to oxygen gas, by means of repeated electric shocks in contact with pure potash, although it attracts oxygen with greater force than nitrous air; the latter being a compound of azote and oxygen.

"When iron is moistened with water, and confined in a glass jar over mercury, it will yield hydrogen. Iron, under the same circumstances in oxygen gas, will give no hydrogen, and the oxygen is condensed; in both cases the surface of the iron is equally oxydized.

"Iron and dry oxygen gas, kept in contact ever so long, will not act on each other: the iron preserves its metallic brilliancy, and the gas its elastic state, and no hydrogen is evolved. Hence it appears, that iron has no effect on oxygen gas in a common temperature, and that it is the oxygen of the water which unites to it, while the oxygen of the gas is condensed by the liberated hydrogen in its nascent state, so as to reproduce water. *This is effected by a double influence, which is so obvious as not to require an explanation. This modification of chemical affinity escaped the observation of chemists before I had written. The process of bleaching is effected in this way.**

" The foregoing facts cannot be accounted for readily. It might be supposed that water condenses muriatic gas in consequence of its capacity for caloric. But why phosphorus, and not ether, oils, or sugar, or why nitrous air, and not azote, unite to oxygen in a low temperature: And again, why iron takes the oxygenous principle from water, in preference to that in its gaseous state, when the hydrogen disengaged condenses it, are phenomena, in my opinion, not well understood.

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* A very ingenious treatise on this kind of affinity was published by Mrs. Fulham, about fifteen years ago, wherein she erroneously attempts to explain the phenomenon of combustion on the same principle, and boasts very much of her discovery, having met nothing like it in the works of Lavoisier, Fourcroy, Kirwan, &c. at the same time that she cautiously omitted mentioning the work from which she borrowed her ideas.

" It is true all this may be attributed to caloric, which, from its attraction to bodies, counteracts their chemical union to each other: yet, from the following considerations, probably some other power interferes.

" It must be allowed that nitrous air consists of oxygen and azote, in the proportion of two of the former to one of the latter. The supposition of its containing phlogiston, will hereafter appear to be erroneous: therefore every ultimate particle of azote must be united to two of oxygen; and these molecules, surrounded with their respective atmospheres of caloric, constitute nitrous air. If these molecules were surrounded with an atmosphere of caloric, equal in size only to those of oxygen gas, 100 cubic inches of nitrous air should weigh 98,535 grains; whereas, according to Kirwan, their weight is but 37 grains.* Hence we may fairly conclude, that the molecules of nitrous gas are thrice the distance from each other that the ultimate particles of oxygen gas are, in the same temperature; consequently we may infer, that their calorific atmospheres are in proportionable size; or some other repelling fluid must interpose.

"Having thus considered the size of the repelling atmospheres of nitrous air, and also the attraction of the molecules of this air to oxygen, which is weaker than that of the ultimate particles of azote in their simple state, it is unaccountable with how much more facility the former unite to oxygen than the latter.

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* Chemists do not agree as to the proportions of the constituents of this gas.

"The decomposition of nitrous gas by the hydrogen of hepatic gas, is also extraordinary, considering, as I already observed, that the hydrogen is not in a condensed state, and therefore very probably combined with its full portion of caloric.

. . . .

"Do atmospheres of equal density favour the union of their respective molecules or particles? Or, do dense and rare atmospheres, by readily blending and suffering them to approach nearer, promote their chemical union? Or, does the electric fluid interfere?

. . . .

"From the foregoing considerations it appears to me that the attractive forces of bodies are not to be estimated by the facility of uniting, but rather by the difficulty of disuniting them. I therefore beg leave to differ from Mr. Kirwan in his objections to Lavoisier's table of affinities, &c. . . . .

"When steam is passed over the surface of fused sulphur in an earthen tube, so contrived as to exclude atmospheric air, hydrogen and sulphurous gases are produced, which shews that sulphur has stronger affinity than the hydrogen to the oxygenous principle, as had been first shewn by Dr. Priestley.*

"According to Mr. Kirwan, 100 grains of sulphur require 143 grains of oxygen gas to convert them into sulphurous acid: they require much more to become sulphuric acid. This acid, exclusive of water, consists of 2 parts of oxygen and 1 of sulphur, by weight.†

"One hundred and forty-three grains of oxygen gas contain 41 of water; quicklime will abstract 26 grains from it, and the remainder of its water cannot be separated by similar means; therefore 100 grains of sulphur require only 100 or 102 of the dry gravitating matter of oxygen gas to form sulphurous acid. As sulphurous acid gas is very little more than double

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[*] Comp. View, page 33. [†] Ibid. p. 36.

the specific gravity of oxygen gas, we may conclude that the ultimate particles of sulphur and oxygen contain the same quantity of matter; for oxygen gas suffers no considerable diminution of its bulk by uniting to the quantity of sulphur necessary for the formation of sulphurous acid. *It contracts* $\frac{1}{11}$ *as shall be shewn hereafter.*

"Hence we may conclude, that an atom of sulphurous acid consists of a single particle of oxygen and a single particle of sulphur, chemically united; and that every molecule of sulphuric acid contains one particle of sulphur and two of oxygen, being the proportions necessary to saturation (*definite proportion*).*

"As two cubic inches of hydrogen gas require but one cubic inch of oxygen gas to condense them to water, we may presume that they contain an equal number of divisions, and that the difference of the specific gravity of those gases depends on the size of their respective particles; or we must suppose that an ultimate particle of hydrogen requires 2 or 3, or more particles of oxygen to saturate it. Were this the case, water, or its constituents, might be obtained in an intermediate state of combination, like those of sulphur and oxygen, or azote and oxygen, &c. This appears to be impossible; for in whatever proportion we mix hydrogen and oxygen gases, or under whatever circumstances we unite them, the result is invariably the same. *Water is formed, and the surplus of either of the gases is left behind unchanged.*

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* Comp. View, page 57.

"When water is decomposed, or resolved into its constituent gases, by the *voltaic battery*, or by an electric machine, the above proportions are constantly obtained.

"From those circumstances we have sufficient reason to conclude, that water is composed of a single ultimate particle of oxygen and an ultimate particle of hydrogen, and that its atoms are incapable of uniting to a third particle of either of their constituents."

It will, I should suppose, be needless to tell my reader, that the foregoing facts, relative to sulphurous acid, sulphuric acid, and water, suggested the first effort of ascertaining the comparative weights of the particles of different elementary matter, and that the weight of the atoms and molecules which they produced, might readily be ascertained, those facts being once established. This part of my theory Mr. Dalton strictly attends to.

"The proportions of the elementary principles of water, sulphuric and sulphurous acids, being thus laid down, let us now attend to their various effects on different substances, according to the antiphlogistic doctrine. *The phenomena which they produce, or rather their chemical action on bodies, were enquired into, on the phlogistic principle, in a part of my Comparative View, preceding that from whence the following extract is taken.*

"It has been observed, that certain metals attract oxygen with greater force than sulphur does, and that the ultimate particles of sulphur have greater affinity to oxygen than those of hydrogen.* It has also been shewn, that sulphuric acid, mixed with water in certain proportion, will oxydize and dissolve metals with more facility than concentrated sulphuric acid, and that water alone will have very little effect on metals in a common temperature.

"Although these facts appear inconsistent when lightly considered, yet they may be accounted for on the following principles, and are, in my humble opinion, inexplicable by any other means whatever.

"Let us suppose iron or zinc to attract oxygen with the force of 7, sulphur to attract it with the force of 6⅞, and hydrogen with the force of 6⅝. Let us again suppose these to be the utmost forces of attraction that can subsist between particle and particle of those substances.

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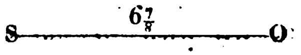
* Comp. View, page 38.

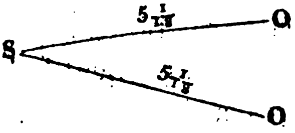
" Stating the relative forces in the foregoing proportion, which I am led to believe is perfectly correct, from facts already adduced, and from many more which will hereafter appear, one would expect that metals should oxydize in water more readily than in concentrated sulphuric acid. This undoubtedly would have been the case if other circumstances had not interfered. The following will be a sufficient illustration.



" Let S represent a particle of sulphur, and O a particle of oxygen, in the annexed diagram, which attract each other with the force of $6\frac{7}{8}$, and let the compound be considered an atom of sulphurous acid; the force of union subsisting between S and O is greater by $\frac{2}{8}$ than that of hydrogen and oxygen in an atom of water, being but $6\frac{5}{8}$.

" As the attraction of bodies is mutual, let us suppose S to possess one half of this quantum of affinity, which is $3\frac{7}{18}$, and O to possess the other half; the two particles must unite with the force represented in the diagram.*

" When a second particle of oxygen unites to the particle of sulphur, its quantum of attraction must be equally divided between both. This will reduce the attachment of sulphur and oxygen in the molecule of sulphuric acid, formed by this triple compound, to $5\frac{1}{18}$.



" *In order to more perfectly understand this part of the doctrine, which I consider to be the most important in the whole system that I advanced,* let S represent a particle of sulphur, and O O two particles of oxygen united to it with the numerical forces annexed to them in the diagram. If one of the particles of oxygen were removed, S and O would remain united with the force of 6$\frac{7}{8}$, and, when restored, this force would be diminished again to 5$\frac{1}{18}$, and so alternately.[*] This seems to be a general law: all bodies unite with greater force to half the quantity of those substances to which they have an affinity, than to the entire. Instance, carbonate of potash will part with a portion of its carbonic acid in a moderate degree of heat, yet it requires a very intense heat to expel the whole. In like manner, crystallized sulphate of potash will part with most of its water in a heat below ignition, but it requires a strong red heat to drive away the entire of its water. Thus we find, in proportion as the potash is deprived of a part of its carbonic acid, its power of retaining the remainder is increased; and the same holds good as to the expulsion of water from the salt [†]

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* Comp. View, page 39.

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[*] Comp. View, p. 40.

[†] Ibid. p. 41.

"The internal structure of water and sulphuric acid being ascertained, what play of affinities must take place when iron or zinc is introduced into dilute sulphuric acid, may readily be conceived.

"The iron will attack the oxygen of the sulphuric acid with the force of 7, which resists only with the power of $5\frac{1}{18}$, in preference to the oxygen of the water, which is held by the hydrogen with the force of $6\frac{5}{8}$. We are not to suppose that the iron will only partially decompose the molecules of acid in contiguity with it, but that it will deprive the sulphur of the entire of its oxygen, more especially when it presents such a multiplicity of metallic particles in a small compass.*

"The sulphur being thus despoiled of its oxygen by a superior power, and still preserving its ultimate division, instantly exerts its whole force $6\frac{1}{8}$ on the oxygen of the water, which it readily gains, meeting with the resistance only of $6\frac{5}{8}$. Thus hydrogen is disengaged."

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* Comp. View, page 42.

The principal object of the foregoing demonstrations was to ascertain that the hydrogen came from the water, and not from the metal, as was almost generally supposed at the time.

Lavoisier and his few followers imagined, that the sulphuric acid first united to the metal, and that the compound, demanding more oxygen, decomposed the water. This is the theory of modern chemists. I have proved the fallacy of this doctrine, as shall be stated presently.

" The phlogistians might object to this mode of accounting for the decomposition of water, by saying that sulphur cannot effect it in the temperature of the foregoing process. I will agree with them, when sulphur is in small aggregates, or molecules; but it should be considered, that fused sulphur, as already observed, will decompose water when brought in contact with it, in the state of steam. This decomposition is effected by means of caloric, which removes the aggregate influence of the ultimate particles of sulphur. If the aggregate attraction should not interfere in a low temperature, which is the case during the rapid decomposition of the molecules of sulphuric acid by metals, the decomposition of water ought to take place the more readily.

" The ultimate particles of sulphur, on being deprived of their oxygen, cannot recover more of it from the water than what is sufficient to form sulphurous acid. This sulphurous acid unites instantly to the metallic oxide, and acts as a solvent."

These movements and arrangements of particles take place with inconceivable velocity.

" When iron is put in concentrated sulphuric acid, scarcely any effect is produced until heat is applied, which removes the aggregate influence of the molecules of the sulphuric acid, and diminishes that of the iron. During this process the iron is oxydized and partly dissolved; sulphurous acid gas is evolved in great abundance, with little or no hydrogen.*

"When water is mixed with the sulphuric acid in sufficient quantity, it interposes itself between its sluggish molecules, and removes them beyond the sphere of their mutual influence: it answers the same purpose that caloric does; so that the solution goes on rapidly without the application of heat.

"The sulphurous acid gas that is produced by the action of concentrated sulphuric acid on iron, may be satisfactorily accounted for in the following manner:

"The first effort of the metallic particles deprives the molecules of sulphuric acid within their reach of the whole of their oxygen, and the particles of sulphur instantly exert the force of 6⅞ on the oxygen of the neighbouring molecules of sulphuric acid, which resist only with the force $5\frac{1}{18}$. As the particles of sulphur can take but one of oxygen from the molecule of sulphuric acid, two portions of sulphurous acid are formed.*

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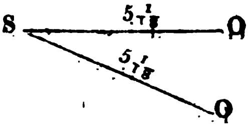
* Comp. View, page 43.

"The following demonstration will render this play of affinity between the particles perfectly clear. Let us suppose a particle of sulphur, recently deprived of its oxygen by the metal, and still possessed of the power of $6\frac{7}{8}$ to recover a portion of it, to be in sufficient contact with a molecule of sulphuric acid, will it not take one particle of oxygen from the sulphuric? And will not the compounds $\mathrm{s}\overset{6\frac{7}{8}}{\overline{\hspace{6em}}}\mathrm{o}$, and $\mathrm{s}\overset{6\frac{7}{8}}{\overline{\hspace{6em}}}\mathrm{o}$, which represent atoms of sulphurous acid, be formed? One portion will pass off in a gaseous state, and the other will unite to the metallic oxide.†



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* Comp. View, p. 44.

† Ibid. p. 46.

" When sulphuric acid is so diluted with water as to afford only hydrogen, the atoms of water, by surrounding those of the acid, or rather by the intermixture of their more numerous surfaces, are exposed to the immediate action of the particles of sulphur the instant they are deprived of their oxygen by the metal : thus only one portion of sulphurous acid is formed, which unites with the oxide, while the hydrogen of the water is disengaged in a gaseous state.

" Agreeable to the foregoing explanation, a fresh made solution of iron in sulphuric acid should contain three portions of oxygen. The following fact will prove this to be the case.

" When potash in solution is poured into a solution of sulphate of iron, immediate decomposition takes place, sulphate of potash is formed, and the metal is disengaged of a darkish blue colour, united with one third the quantity of oxygen necessary to its perfect oxydation. The metal could not receive this oxygen, from the sulphuric acid being found united to the alkali in its perfect state, otherwise we should obtain a sulphite of potash. . . ."

*This decomposition, and also that which the solution of iron undergoes by long exposure to the oxygen of the atmosphere, have been demonstrated by means of diagrams, upon unerring mathematical principles, in continuation of the foregoing extract, in my "Comparative View."**

Its full quantum of influence has been given to every particle, distinct from each other. And I am certain that chemical philosophy will never reach its meridian splendour, except by means of such principles.

The maintainers of the phlogistic doctrine allowed that metals must part with their phlogiston (hydrogen) in order to become soluble in acids. As no hydrogen is given

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* Comp. View, pages 47—49.

out when metals are dissolved in highly concentrated sulphuric acid, they insisted that the sulphurous gas evolved contained the phlogiston of the metal; that is, this acid gas is a compound of sulphuric acid and hydrogen. The foregoing demonstrations were intended to prove the fallacy of that part of their doctrine. They were, however, considered inadequate: more decisive experiments were necessary for the purpose.

It occurred to me, if sulphurous acid contained hydrogen, should it dissolve metals, that a double quantity of hydrogen would be obtained, (its own hydrogen and that of the metal). The chemical properties of sulphurous acid were scarcely known at this time.

The following experiment was of considerable importance, as it helped very materially to upset the phlogistic doctrine, and to establish the new philosophy which I adopted, in order to investigate the antiphlogistic system.

"I introduced some iron nails, free from rust, into strong sulphurous acid; in a few minutes it acquired a milky appearance, and the solution went on, *to my great astonishment*, without ebullition or extrication of gas, of any kind. On standing a few hours, the solution acquired a darkish colour, and cleared soon again by the deposition of a black powder. This powder, when collected and washed, burned on red hot iron like charcoal with a small quantity of sulphur."*

This acid is an excellent menstruum for analyzing iron or steel, for the whole of the carbon they contain is left behind in the solution, which is not the case when they are dissolved in other acids. The French chemists brought this forward as a new discovery of their own, seven years after my Comparative View had been published. As I have taken sufficient notice of this transaction in the preface to my Essay on Bleaching, together with the change which nitrous acid

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* Comp. View, page 49.

produces on blood, which Fourcroy assumed to himself, it is needless to comment on the subject here.

" A neutralized solution of sulphite of iron is quite clear, of a light greenish colour, and free from any sulphurous smell. When nitrous acid is dropped into the solution, a cloudiness is produced, which immediately disappears without ebullition, although sulphurous acid is disengaged, in its peculiar degree of pungency, which was not expected : on the contrary, nitrous gas was looked for.* The sulphuric, muriatic, and acetous acids, decompose this solution, and no hydrogen is disengaged.

" The prussiate of potash throws down a white prussiate of iron, which, by exposure to the atmosphere, gradually acquires a blue colour: this change is produced instantaneously, when exposed to oxymuriatic gas."

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* Comp. View, page 50.

I will pass over the various applications of those facts in the enquiry which engaged my attention at this remote period, and confine myself to the following extract:

"It may appear extraordinary that hydrogen is not produced during the solution of iron in sulphurous acid, whereas it is so copiously evolved by its solution in dilute sulphuric acid, which contains double the quantity of oxygen."*

Should the hydrogen be obtained by the decomposition of water, one would suppose that the sulphurous acid, which contains less oxygen by one half than the sulphuric acid, would effect it more readily. If the decomposition were occasioned by the compound resulting from the acid and iron, it would be the case.

"I confess I was much puzzled for a considerable time, before I could reconcile these seemingly clashing pheuomena to my theory.† It appears to me that they are demonstrable in the following manner, and in no other way whatever.

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* Comp. View, p. 50. † Ibid. p. 59.

" Let us suppose iron to attract oxygen with the force of 7, and sulphur, from the divided attachment of its particles to a double portion of oxygen, to retain it with the force of $5\frac{1}{18}$, as usual; let us also suppose iron, from the density of its texture, to present a greater number of ultimate particles in a given surface than the sulphuric acid, particularly the dilute acid, from the interposition of water.*

" From the foregoing statement of the relative forces of attraction subsisting between the particles of those substances, the following decomposition must take place. When dilute sulphuric acid and iron are exposed to each other's chemical influence, the martial particles will take the whole of their oxygen from the molecules of the acid, or their particles of sulphur, in consequence of an attraction for iron, which is very small, comparatively to the opposite powers, will move along with their oxygen. This is not likely to take place; for the force of 7, exerted by the iron on the oxygen, separates it from the particles of sulphur with such celerity that the latter are left far behind, and being in contact with water, they exert their whole force on its oxygen.

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* Some diagrams are omitted here, which were considered unnecessary, therefore instead of referring to the letters of those diagrams which represented particles, I shall mention them by their proper names,

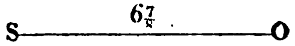
" Therefore it is the superior force of the metal, and the proportional velocity of the motion of oxygen towards it, that leave the particles of sulphur so circumstanced as to enable them to decompose water in the manner already described."

It might appear strange to persons not intimately acquainted with chemical philosophy, that velocity and motion should be taken into consideration when bodies seem to be in contact with each other. The particles of the most solid substances are not in complete contact; and the atoms or molecules of fluids are still more remote from each other.

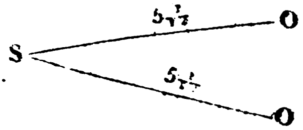
Probably if the diameters of those divisions could be ascertained, the space they have to move through, in order to form a chemical union, would be very considerable.

We will now attend to the effect of sulphurous acid on iron, which places my doctrine on the decomposition of water beyond the smallest doubt.

" When sulphurous acid is poured on iron, although its particles attract the oxygen of this acid with the force of 7, yet it meets with the resistance of $6\frac{7}{8}$, as the diagram, which represents an atom of sulphurous acid, will shew.

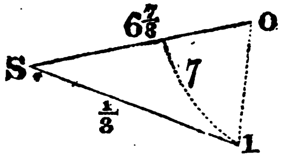


" The same superiority of force does not prevail here between the particle of sulphur and that of the iron for oxygen which evinces itself in the molecule of sulphuric acid.



" Had there been a greater inequality of force between S and the particle of iron for oxygen, S from its intimate union to its oxygen O and a small degree of attraction to iron, would move with its oxygen towards the iron, and form the molecule of sulphite of iron already described.*

" The following diagram will help to render those affinities very clear.



S represents a particle of sulphur, O its oxygen united with its usual force. I represents a particle of iron, figure 7 represents its force of affinity to oxygen, and the fraction $\frac{1}{8}$ represents its influence on the sulphur. This shews, although the particle of iron attracts the oxygen with the numerical force annexed to it, that the sulphur is influenced with the same force by the particles of iron and oxygen conjointly, which is the power of 7; therefore the oxygen and its sulphur will move with equal speed, and unite to the particle of iron. Hence it is that no separation of the principles of the sulphurous atom takes place, that water is not decomposed, and that no hydrogen is produced.

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* Comp. View, page 60.

"The foregoing facts and demonstrations, relating to the sulphuric and sulphurous acids, confirm each other, and throw light upon many abstruse chemical phenomena."*

Still, however, it occurred to me, at this time, that it was necessary to ascertain the proportions of the principles of the sulphurous acid, more especially as it was considered by eminent philosophers a compound of hydrogen and sulphuric acid. In order to this I made the following experiments.

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* Comp. View, page 61.

"I mixed equal parts of sulphuretted hydrogen obtained from iron filings and sulphur, (previously exposed to heat sufficient to unite them,*) and oxygen gas produced from nitre. The sulphuretted hydrogen was absorbed by water to a very small bubble, and the oxygen contained but one tenth of azote.†

"Nine measures of this mixture (3 cubic inches) were reduced by the electric spark to 2½; the nitrated solution of barytes condensed them to one twelfth of a measure, or somewhat less; and the solution did not appear in the smallest degree turbid; and no cloudiness was produced by the addition of lime water. The residuum left unabsorbed was too small to be examined; the portion condensed by the solution seemed from the smell to be sulphurous acid. In order to be convinced of this, I inflamed another charge of the same mixture of gases, and transferred the residuary air to a clean tube, which the sulphur, deposited on the sides of the inflaming jar, obliged me to do. To this residuum an equal bulk of sulphuretted hydrogen was added, which instantly rendered it turbid, and reduced it to about one third.

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* The sulphuretted hydrogen is obtained from this compound by means of dilute sulphuric acid.

† Comp. View, pages 78—81.

"This assured me that the gas was sulphurous acid, and also that this acid will not decompose nitrate of barytes.

"These experiments not only prove the constituent principles of sulphuretted hydrogen, but absolutely prove what I have advanced respecting the proportion of the elementary particles of sulphurous acid.

"It has been shewn by Dr. Austin, that hydrogen gas suffers no diminution or increase of its volume by the union of sulphur; therefore one half of the mixed airs was hydrogen independent of its sulphur, that is, 4½ of hydrogen gas. These 4½ measures require 2¼ of oxygen gas to condense them into water. 2¼ more of oxygen were expended in the experiment, two of which must exist in the sulphurous acid; and, as much of the azote disappeared, we may conclude that the remainder of the oxygen (¼ of a measure) was expended in the formation of nitrous acid.

"From the foregoing facts it is evident, that the two measures of sulphurous gas contain two measures of oxygen; and as the specific gravity of sulphurous gas is double that of its constituents, excluding the hydrogen, we may infer that only the sulphur of two measures united to the oxygen gas, and that the sulphur of 2½ measures was precipitated.*

"We may also infer from these data, that the atoms of sulphurous gas are surrounded with as large atmospheres of caloric as the particles of oxygen gas, or that they are as far asunder; and that the number of the ultimate particles of sulphur in sulphuretted hydrogen are to those of the hydrogen as 9 to 5." *According to the experiment, they are as 18 to 9. Further experiments must correct inaccuracies. These will soon follow.*

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* Comp. View, page 81.

This was the first experiment of the kind made, and, had there been no other evidence brought forward, ought to be sufficient for the purpose, as it establishes three important facts which comprehend the whole of what has been unjustly called Dalton's Theory. 1. The proportion of the constituents of an atom of sulphurous gas, and the relative weight of those elementary principles. 2. The weight of the atom, and comparative diameter of its calorific atmosphere. And lastly, The proportion of the ultimate particles of hydrogen, and of sulphur, in sulphuretted hydrogen gas.

The following experiments were made since I commenced writing this essay. They will confirm what I originally advanced respecting the quantity of oxygen and sulphur in sulphurous acid.

I introduced a small bit of brimstone into a glass tube 37 inches long, previously filled with quicksilver and inverted in the same fluid; it was curved at the sealed end, in order to separate the brimstone from the surface of the mercury. The brimstone was partially fused in the vacuum, to make it stick to the glass when cold. Five cubic inches of oxygen gas were then thrown up; the sulphur was melted by the flame of a spirit lamp, and when sufficiently heated, a flash was produced with a slight concussion of the apparatus. Upon increasing the heat, a second flash took place with a blue flame: no further effect could be produced. On suffering the apparatus to cool, and restoring the pressure of the atmosphere, by an inclination of the tube, evident contraction appeared: when water was introduced the diminution was very considerable.

These appearances induced me to change my apparatus, and make more accurate trials. A small quantity of sulphur was introduced into a glass tube a foot long, curved as the former; the sulphur was made to adhere to its extremity by fusion; when cold, it was filled with mercury, and a cubic inch of oxygen gas was thrown up; and the space, occupied by the gas in the measure used, was accurately divided into twelve equal parts.

When sufficient heat was applied, the combustion of a portion of the sulphur was effected with a sudden flash, accompanied with a considerable concussion, similar to what takes place when oxygen and hydrogen are fired by the electric spark. In about a minute after, a second explosion took place, and a languid blue flame appeared on the surface of the fused sulphur, which lasted a few seconds. No further change was produced by a continuation of the heat, although the end of the tube, where the sulphur was placed, was made obscurely red.

When the apparatus cooled to the temperature of the air of the elaboratory, the gas was transferred to the cubic inch measure; the contraction appeared nearly $\frac{1}{11}$. When water was sent up to condense the sulphurous gas, one part remained unabsorbed, which was found to be oxygen gas.

If the whole of the oxygen had united to sulphur, the contraction, upon the most accurate calculation, would have been $\frac{1}{11}$. The experiment was repeated with similar result.

It is impossible to convert the whole of the oxygen into sulphurous acid, in these experiments, from the interference of the acid gas formed, which excludes a portion of the oxygen from contact with the sulphur.

When the oxygen gas was increased so as to have nearly a cubic inch of it expended, the contraction was invariably [illegible].

The foregoing fact being ascertained, the results of the following experiments can readily be accounted for.

Five measures of a mixture of 23 of oxygen gas and 10 of sulphuretted hydrogen, were fired by the electric spark, and reduced to 2¼; no sulphur was left, and a residuum of oxygen gas remained when the sulphurous gas was condensed by water. Sulphuric acid was formed in this experiment.

When the oxygen gas was reduced to 21 parts, and 10 of sulphuretted hydrogen, sulphuric acid was also formed, but in less quantity than in the last experiment, and some oxygen was left.

In one experiment 9 cubic inches of oxygen and 1 of sulphuretted hydrogen (in all 30 measures) were fired, and reduced to 13 measures, and no oxygen remained;

about $\frac{1}{10}$ of azote was the only residuum.

This last experiment was repeated with gases carefully made; the sulphur was completely consumed, and 4 measures of oxygen gas were left. Several trials gave the same result.

These experiments led to the proportion of the gases sufficient to saturate each other, which was the principal object.

A mixture of 16 of oxygen gas and 10 of sulphuretted hydrogen was prepared; of this $6\frac{1}{3}$ measures were fired, and reduced to $2\frac{2}{3}$; no oxygen was left. When water was introduced, the sulphurous gas was condensed, and a very small bubble remained, which must be azote: by the test of muriate of barytes a very slight vestige of sulphuric acid appeared.

In this experiment 5 parts of the oxygen must have been expended in condensing the hydrogen into water; 11 parts more must go to the sulphur, in order to produce sulphurous gas: making an allowance for contraction and for azote, the whole of the oxygen is thus accounted for.

The following experiment was made with a view to ascertain, whether the last proportions of the gases were sufficient to saturate each other.

A mixture of 15 of oxygen and 10 of sulphuretted hydrogen were fired; a small portion of sulphur was deposited, and the sulphurous gas measured little more than 9; muriate of barytes shewed a slight appearance of sulphuric acid: there was a small bubble of azote left as usual.

The gases used in these experiments were dried by means of fused muriate of lime, and they were examined under the same pressure of mercury before and after their union.

The foregoing facts prove that 10 measures of sulphurous gas contain 11 measures of oxygen gas, and as the specific gravity of this compound gas, making an allowance for the contraction of the oxygen on uniting to sulphur, is but twice that of its constituents, it is evident that a particle of sulphur contains the same quantity of solid matter which a particle of oxygen does, and that a sulphurous atom consists of a single particle of oxygen and a single particle of sulphur.

Should sulphurous gas, according to Mr. Dalton, contain two portions of oxygen and one of sulphur, considering that there is no expansion produced by the union, it would be more than one third heavier. But whence could this second portion of oxygen come? For, the whole of the oxygen expended in my experiments has been accurately accounted for.

Besides, the quantity of sulphurous acid, which a given measure of oxygen is capable of producing, puts the question beyond a doubt; and also confirms the inference drawn from the first experiments, which I made *twenty-three years ago* on this subject, " that the proportion of ultimate particles of sulphur in hepatic gas is to those of the hydrogen as 2 to 1 nearly."*

As sulphurous gas and sulphuretted hydrogen gas, when mixed, decompose each other, in the common temperature of the atmosphere, water being formed and sulphur deposited, I was anxious to know the exact proportion in which these gases condense each other. After a few trials I found the following proportions to answer.

22,50 measures were passed into a graduated glass tube filled with quicksilver; 28 measures of sulphuretted hydrogen were introduced: the whole of the gases was reduced to one measure, and the part of the jar, in which the condensation took place, was lined with sulphur.

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* Mr. Dalton supposes that this gas consists of 3 of hydrogen and 1 of sulphur. In this he corrects himself in the second part of his work, and considers the gas to consist of 1 of hydrogen and 1 of sulphur. This amendment is equally incorrect, so that he falls from one error into another.

I did not expect that the sulphuretted hydrogen would decompose such a quantity of sulphurous gas; for the 22,50 measures, allowing for contraction, contained 24,50 of oxygen nearly; 14 of this quantity was sufficient to convert 28 measures of hydrogen into water. The remaining 10,50 must have been carried down, in the state of sulphurous acid, with the precipitated sulphur of both gases.

Mr. Dalton and many more chemists suppose, that there is an oxide of sulphur formed in this process, which consists of a particle of sulphur and one of oxygen.

This cannot be the case; for I have proved that sulphurous acid consists of these proportions. It is more probable that the sulphurous atoms are somehow or other influenced by a portion of the particles of the sulphur, at the moment of their liberation, in the same way that sulphurous acid is condensed by the sulphuric, without a decomposition of their respective atoms and molecules; instance the glacial oil of vitriol of the ancient chemists, which is obtained from sulphate of iron by a strong heat. However, this can only be ascertained by experiments.

A portion of the sulphur deposited from the gases was collected from the glass jar, as free from globules of mercury as possible. It was then pressed and kneaded between the fingers, in order to force out any remaining quicksilver: by this mechanical process the mass acquired a considerable degree of cohesion and elasticity, had a strong acid taste, and the smell of sulphurous acid, although it was formed with an excess of sulphuretted hydrogen. By continuing the process, it became softer and more pliable, and the acid taste and smell were scarcely perceptible, and in a short time vanished altogether.

While working it up, I dipped my fingers at intervals in a small glass of distilled water, in order to collect the acid pressed out, and they were perfectly dried each time before the operation was resumed. On examining the water, it was found to contain sulphuric acid.* Neither cold nor warm water had any effect on this substance; but, when boiling water was poured on it, the cohesion of its parts was destroyed, and the water exhibited a milky appearance; the solution was evaporated to dryness, and a small quantity of distilled water was added; when filtered, muriate of barytes produced a very slight cloudiness, which shewed that the whole of the acid was not removed by pressure. What remained on the filter was sulphur mixed with some black matter. Potash, by means of heat, dissolved the whole of the sulphur which this substance contained, and left a black powder behind, which burned on red hot iron like charcoal, without the smallest appearance of sulphur. Carbonate of potash seemed to have very little action on it; for the small piece, exposed to it in a very moderate degree of heat, retained its shape and bulk, but readily crumbled between the fingers into a black powder, consisting, apparently, of carbon and some sulphur.* Alkohol produced no change, and ether had no effect on this substance.

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* This fact proves that the sulphuric acid is formed at the moment of the condensation of the gases, and that water is not necessary to its formation, as Dr. Thomson and Mr. Dalton supposed. By what play of affinities it is produced I know not, unless it be the following. The ultimate particle of sulphur, the instant it is set free in the gases, exerts its aggregate influence on the particle of sulphur of its neighbouring atom of sulphurous acid, while the oxygen of this atom passes over to another atom of sulphurous acid in its vicinity, so as to constitute a molecule of sulphuric acid. This double influence might produce the effect. The small quantity of sulphurous acid, which appeared, might be carried down mechanically by the sulphur and sulphuric acid.

Presented to the flame of a candle, it burned somewhat better than sulphur;

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* These are to be considered the properties of the gummy substance, when produced in its perfectly elastic state and deprived of the acid.

and nearly its bulk of a very porous and light black substance remained. This black matter I suspected to be carbon.

A portion of this black powder was introduced into a curved tube filled with oxygen, and inverted in quicksilver. The carbon was confined to the curved part. When it was sufficiently heated by the flame of a spirit lamp, it burned with very brilliant scintillations, and no residuum was left. Lime water was thrown up as soon as the apparatus cooled, which became turbid in a few minutes. These facts assured me that this black substance was pure carbon. To perfect the combustion of the carbon in oxygen, it must be previously freed of the whole of the sulphur by heat, which should be gentle at first, to avoid the joint combustion of the carbon and sulphur: when the latter is nearly expelled, the heat may be raised to any degree that will not promote the combustion of the carbon.

To ascertain the quantity of charcoal in this gummy substance, I exposed three grains of it, on a watch glass, to a moderate heat, and although it parted with a small quantity of sulphur, its elastic property was very little impaired.

When the heat was increased by the flame of a spirit lamp, it ignited, and the remaining sulphur burned with a blue languid flame with a few scintillating sparks. As soon as the combustion of the sulphur ceased, the black matter remaining was considerably heated, in order to expel the whole of the sulphur. It weighed half a grain.

It is probable from the foregoing facts, that this kind of elastic gum consists of hydrogen, carbon, and oxygen. It is extremely difficult to ascertain whether sulphur is necessary to its constitution. As the pure sulphur deposited from the gases incorporates with it when worked up together, we have reason to suppose that the union of most of the sulphur is somewhat mechanical.

To ascertain as nearly as possible the quantity of sulphur produced by the gases, and to obtain it free from mercury, a stratum of water was sent up in a jar filled with quicksilver; 7,6 cubic inches of sulphurous acid were then passed up, and 10,8 of sulphuretted hydrogen. Almost the whole of the sulphur remained suspended, and passed through a filter. The liquor was evaporated to dryness, in a gentle heat; sulphur and a very small quantity of sulphuric acid were left. The weight of the sulphur could not be ascertained, as it contained some minute globules of mercury.

The experiment was repeated, with the difference of employing ether instead of water. The sulphuretted hydrogen was first sent up; it was readily condensed by the ether without any degree of turbidness whatever.* The sulphurous gas, in the proportion last mentioned, was introduced; the sulphur fell down in the ether, in small flocks; when it had stood for a few hours, the ether became nearly clear, and the sulphur rested on the surface of the mercury. Atmospheric air was suffered to pass into the jar in sufficient quantity to displace the whole of the quicksilver; the sulphur was separated by means of filtration, and the ether passed through quite limpid; but, when partly evaporated in a moderate heat, it became milky. When the whole of the ether was evaporated, a very minute quantity of sulphuric acid and sulphur, of a dark colour, were left behind, the weight of which could not be ascertained.

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* Ether unites to 7 times its bulk of sulphuretted hydrogen gas without any apparent change. This hydro-sulphuretted ether might be found of some use when its properties are fully ascertained.

The sulphur, which the ether left on the filter, was washed with distilled water. When this water was evaporated, no residuum remained. When the sulphur was dried, it weighed 10 grains. It was exposed to a sufficient heat to volatilize the whole of it, except a small quantity of charcoal.

The foregoing experiment was repeated, and water was used to depress the quicksilver, in order to obtain the ether and sulphur free from mercurial globules, which is almost impossible. The liquid was evaporated to dryness, and then exposed to heat sufficient to expel the sulphur; a dark brown residuum remained, which formed a kind of varnish on the bottom of the saucer, in which the experiment was made. The heat applied to produce this effect was about 700° of Fahrenheit. When a small portion of this varnish was collected, it burned with some difficulty on red hot iron, and a minute quantity of grey ashes was left.

Some ether was passed up into a tube filled with mercury; about thirty times its bulk of sulphurous gas was afterwards introduced; the whole was absorbed, yet the ether was not sufficiently saturated with it; sulphuretted hydrogen was then sent up in as small quantity as possible at a time: some sulphur was deposited on the surface of the sulphurous ether, which, in descending in streaks through the liquid, was re-dissolved.* When one third or thereabout of the sulphurous acid was thus saturated, water was introduced; the ether and sulphur rested on the surface of the column of water. When the two fluids were mixed, a portion of the sulphur disappeared. When the liquid was evaporated, sulphurous acid was expelled, and sulphur and carbonic matter remained behind, with a small portion of sulphuric acid.

In order to ascertain whether the sulphur, the moment it was disengaged from the hydrogen, had been dissolved by the sulphurous acid or ether, water was substituted for the latter, and no evident re-dissolution appeared. It is therefore probable that the two former fluids co-operate in producing the effect.

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* The quantity of sulphur thus dissolved is barely perceptible.

The following experiment was made, to ascertain the quantity of sulphur deposited by a certain portion of the two gases, and also to ascertain the quantity of carbon.

7,6 cubic inches of sulphurous gas, and 10,8 of sulphuretted hydrogen, were mixed over quicksilver; after the condensation was effected, the sulphur was carefully collected; very dilute nitrous acid was poured on it to dissolve some small globules of quicksilver which adhered to it; when it stood for two days, the quicksilver was taken up. The sulphur was collected and washed, and when perfectly dry weighed 7½ grains. It was exposed to heat sufficient to expel the whole of the sulphur; half a grain of charcoal remained.

As the quantity of sulphur obtained in this experiment was less than could be expected, some of it must have been oxydized by the nitrous acid. The quantity of sulphur obtained (10 grains) in a former experiment, from 18,4 cubic inches of the gases, is the nearest approximation to the real portion which they contain, as may be deduced from the additional weight, which oxygen and hydrogen acquire by their union to sulphur.

It is remarkable that the gummy matter is never formed when water or ether is used, although charcoal and sulphuric acid are constantly produced, unless we except the experiment, in which a varnish was formed. In the latter I succeeded but once, although the experiment was repeated. Probably the large quantity of ether, which was used in this experiment, contributed to the effect, by affording an additional quantity of carbon and hydrogen; for the portion of ether used was not attended to with any degree of accuracy, being considered of very little consequence.

The object of my enquiry was to ascertain whether a compound of the fixed oxide of sulphur existed. And my experiments tend to prove *that there is no such substance.*[*]

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[*] A glass jar, fitted with a brass cap and stop cock, was filled with quicksilver; about sixteen ounce measures of sulphuretted hydrogen were then passed up, and transferred into an exhausted glass globe of the same capacity. The glass jar was then filled with sulphurous acid gas; a communication being formed by means of the stop-cocks, the latter gas was gradually pressed up into the globe. A rapid condensation of the gases took place, and the quicksilver ascended so as to fill the jar. The whole of the inside of the globe was encrusted with sulphur, of a deep lemon colour, and, when collected, exhibited a crystalline appearance in very minute and brilliant spiculæ. The globe was considerably heated by the union of the gases, but not so much as one would expect from the condensation of such a large quantity, which shews that these gases contain very little caloric, notwithstanding the size of their respective atmospheres.

A portion of this sulphur was examined for carbon, in the manner already described, and the quantity obtained was nearly equal to that found in former trials.

When hot distilled water was poured on some of the sulphur, it became milky, and a strong smell of sulphurous acid was produced. This milky liquor, being separated from the sulphur, and evaporated to dryness, left a small residuum of sulphuric acid and carbon, and the washed sulphur also gave carbon. This experiment proves that none of the carbon, or black matter, comes from the mercury.

A large quantity of sulphuric acid was mixed with sulphur. This mixture was exposed in a glass cup to sufficient heat to fuse the sulphur, and to evaporate a great part of it and the whole of the sulphuric acid. No sulphurous acid was produced, and the remaining sulphur was not changed in the smallest degree.

I exposed fused sulphur to sulphurous acid in a glass tube over mercury for a considerable time, and no change whatever was produced in the gas or sulphur.

Now, were it possible to produce an oxide of sulphur, it ought to have been formed in the last two experiments, particularly by the sulphuric acid, as containing, according to Mr. Dalton's proportions, 1 of sulphur and 3 of oxygen, proportions different from the estimate, which I advanced in my "Comparative View," and which is founded on unerring principles. It is upon that account I have dwelt so much upon this subject.

The carbon obtained in the foregoing experiments must come from the sulphuretted hydrogen, and this gas received it from the sulphuret of iron, the substance, together with sulphuric acid, which produced it; yet the whole of the sulphuretted hydrogen was condensed by water, and no residuum of carbonated hydrogen remained.

I was anxious to produce this gas from iron free from carbon, but I found by my excellent test, (the sulphurous acid) that all kinds of iron contain more or less of it, except native meteoric iron: of this I had not a sufficient quantity. I attempted to reduce pure oxide of iron to its metallic state in hydrogen gas, by means of a lens; but the sun was not sufficiently powerful at this season of the year (December) to produce the desired effect.[*]

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[*] When I used sulphuretted hydrogen obtained from the sulphuret of potash, no carbon was produced.

I could not conceive the cause of the dark colour of the sulphur precipitated, when equal measures of sulphuretted hydrogen and oxygen were fired, until I discovered the presence of carbon in the gummy matter already described; and in proportion as the quantity of oxygen was increased, the colour of the sulphur was still darker, because the whole of the carbon was deposited, and less sulphur. From what we know of chemical affinities, the carbon should first unite to the oxygen, the sulphur next, and the hydrogen last of all; yet this, strange as it may appear, is not the case, for the very reverse takes place in this experiment.

But what is still more singular, when a mixture of sulphuretted hydrogen and oxygen, in a small excess of the latter, was fired, the carbon was deposited and appeared in very minute divisions on the surface of the quicksilver; lime water was thrown up, which condensed the sulphurous acid; no degree of turbidness appeared, and a small residuum of oxygen was left; therefore no carbonic acid was formed.

This subject deserves more attention than I can bestow on it at present.

Nitre and nitrous acid helped very much to prove, during my researches, the fallacy of the phlogistic doctrine, and also to establish the atomic system. My first object was to ascertain the quantity of azote and oxygen, that existed in this acid. This was accomplished in a variety of ways, but particularly by resolving those principles into gases, which is readily effected when nitrate of potash is exposed to a strong heat. As the gases are obtained mixed in various proportions at different stages of the process, the whole of the product was received in one mixed volume, and carefully examined.* The proportions were 1 of azote and 5 of oxygen. Lavoisier, at the same time, estimated the proportions as 1 to 4. If his inference rested on the decomposition of the pale nitrous acid, he must have been correct.

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* Comp. View, p. 83.

The quantity of oxygen contained in nitre being once ascertained, its expenditure could readily be accounted for, when metals, charcoal, or sulphur, decomposed this salt by means of heat, as the oxides or acids produced must contain the whole of the oxygen, or else some of it must be expended in uniting with the hydrogen or supposed phlogiston of those inflammable bodies so as to form water.

I shall not now detail the great variety of experiments made for this purpose. I will only attend to that part, which more immediately relates to the atomic doctrine.

. . . . "Thus two parts of nitre and one of sulphur will detonate, when exposed to sufficient heat, at the same time that the whole of the acid is decomposed.* Sulphur will not unite to more oxygen, in the degree of heat necessary to conduct this process, than is sufficient to convert it into sulphurous acid; or, if it even should, its attraction is not strong enough to take any more of it from the nitre, as has been shewn in the third section of this work. Therefore we obtain from the above proportions sulphurous acid gas, oxygen gas, and azotic gas; there is also some sulphur sublimed at the commencement of the process.

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* Comp. View, pages 121, 122.

"When one part of sulphur, and four of nitre, are used, the products are quite different; for the quantity of sulphur being very small, it presents but a few surfaces to the nitre, so that it can only take the portion of oxygen from it, which is over and above the quantity contained in nitrous gas: the nitrous gas, being thus deprived of its oxygen, can no longer be retained by the alkali. The reason no deflagration takes place in this experiment is, the atoms of sulphur being few, relatively to the molecules of nitre, and so separated by their interposition, the quantity of caloric disengaged by the more intimate union of the oxygen of the nitre to the sulphur is insensibly dissipated; that is, it is not liberated in a sufficient degree of accumulation to present the phenomenon of combustion. The reverse of the foregoing takes place, when a larger quantity of sulphur is used; for in this case, the atoms of sulphur being more numerous, and of course closer to each other, caloric is disengaged in a more concentrated state, at the same time that the whole, nearly, of the oxygen of the nitre is taken up.*

" In order to deprive the nitre of all its oxygen, it is necessary to use sulphur in excess. First, because an ultimate particle of sulphur can only take a particle of oxygen from the nitre. 2. As every molecule of nitre contains, most commonly, four ultimate particles of oxygen and one of azote, which, forming little aggregates, and being enveloped by water of crystallisation, and the alkali, are in a great measure defended from the action of the sulphur.*

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* Comp. View, page 123.

"Therefore, as the nitre cannot be divided so ultimately as sulphur, if only that quantity of the latter be mixed with nitre, which will expose only surfaces sufficient to deprive its molecules of one half of their oxygen, nitrous gas is evolved; but if, on the contrary, a sufficiency of sulphur be used to deprive the molecules of nitre of $\frac{3}{4}$, or thereabout, of their oxygen, we obtain azotic, sulphurous, and oxygen gases.

"Charcoal detonates with nitre in various proportions, but in no proportion will it disengage nitrous gas.

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* The weight of the nitric acid molecule, united to an atom of potash, can readily be deduced from the weight of its constituent gases, when perfectly dry; but the weight of the compound molecule of the salt described above cannot, in my opinion, be ascertained, in consequence of the interference of doubtful quantities of water. Mr. Dalton has attempted to ascertain the weight of the molecules of many saline substances.

" Charcoal and nitre, distilled in many proportions, will afford azotic gas, and carbonic acid gas, and no nitrous gas whatever. I would ask the phlogistians, &c. . . . .[*]

" Charcoal not only unites to a larger quantity of oxygen than sulphur does, in order to become sulphurous acid, but it also attracts the portion necessary to its conversion to carbonic acid with greater force.[†] Thus it is, that charcoal, mixed with nitre in a very small proportion, will detonate, and that azotic gas and carbonic gas are produced. Every single molecule of charcoal (for we cannot reduce it to its ultimate particles by attrition) is capable of depriving a single molecule of nitre of the whole of its oxygen ; this decomposition is so rapid that the molecule of charcoal directs the whole force of its attraction towards the molecule of nitre, which first influences it; otherwise the charcoal would take a portion of oxygen from different nitrous molecules at the same time, so as to disengage nitrous gas."*

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[*] Comp. View, p. 125.

[†] At this early period I was aware that a molecule of carbonic acid consisted of 1 particle of carbon and 2 of oxygen.

I will pass over several experiments made on different metallic filings and nitre. As they were intended to prove the non-existence of hydrogen in those substances, they could not be interesting at present.†

I shall adduce one of many experiments made on arsenic, as it, in some measure, relates to the principal object of this work.

"When regulus of arsenic, and nitre in powder, are mixed, and projected into a red hot crucible, a rapid deflagration ensues; the nitric acid is completely decomposed, and of course no nitrous gas is produced.

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* This passage proves that I considered the molecules of this salt distinct and independent of each other; and of course, the idea extended to all saline bodies; for what holds good in one, must relate to the whole tribe. Mr. Dalton may weigh those molecules, but he must allow that they were first *identified* by me.

† Comp. View, page 128.

"When the oxide is treated in the same way, the nitric acid of the nitre is only partially decomposed; for nitrous is evolved, and no deflagration takes gas place.

"The regulus of arsenic having greater attraction to oxygen, and being capable of uniting to more of it than its oxide, which is already half saturated with it, wholly decomposes the nitrous acid of the nitre; and, as a great number of the particles of oxygen accumulate with such rapidity in a given time and space, the phenomenon of combustion is produced.*

"The reverse of this takes place, in a great measure, when the oxide is used instead of the regulus; for it can only take a certain portion of oxygen from the nitre, and it attracts this quantity with less force than that which is barely necessary to its calcination, (*to its first stage of oxydation.**)

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* Comp. View, p. 129.

As no hydrogen is produced during the solution of metals in nitrous or nitric acid, the nitrous gas evolved was supposed to contain it. This induced me to make the experiment with the oxide of arsenic, which, although it could impart no inflammable principle, produced nitrous gas.

Nitric acid was known to consist of azote and oxygen some time before I wrote my Comparative View, and the volumes of the gases, which compose it, were ascertained by Lavoisier and myself; but its internal structure or disposition, or arrangement of its particles, was totally unknown until I had

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* The different degrees of the oxydation of metals were as well known to me at this period as those of other inflammable substances; but there was no nomenclature to designate them.

written on the subject. It is somewhat singular that no chemical writer has ever glanced at this circumstance, although it is twenty-four years since I published my book. This appears still the more extraordinary, as this kind of anatomy exhibited the most leading features of the atomic theory and definite proportions. Posterity, no doubt, will be surprized at this oversight, and will do my efforts that justice, which my cotemporaries have withheld. Here follows the extract on this subject, without any material alteration whatever.

"Having treated on the decomposition of nitre, let us now attend to the nature of nitrous acid in its simple state.[*] To account for the variety of changes, which this acid is capable of undergoing by the mediation of different inflammable substances, it will be necessary to be acquainted with the force, by which its constituent principles are united.

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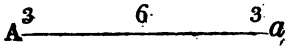
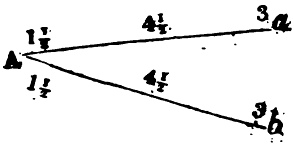
[*] Comp. View, pages 132-3.

"In my opinion, the most perfect nitrous acid contains 5 of oxygen and 1 of azote. Nitrous gas, according to Kirwan, contains 2 volumes of oxygen gas, and 1 of azotic gas. According to Lavoisier, 100 grains of nitrous gas contain 32 grains of azote and 68 of oxygen. I am of the former philosopher's opinion. I also am of opinion, that every primary particle of azote is united to 2 of oxygen, and that the molecule, thus formed, is surrounded with one common atmosphere of caloric.

"As this requires demonstration, let A in the annexed diagram represent an ultimate particle of azote, which attracts

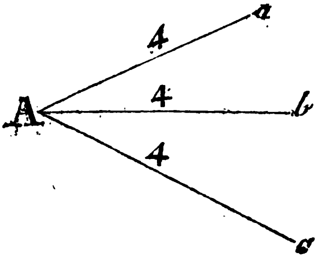


oxygen with the force of 3; let *a* be a particle of oxygen, whose attraction to A we will suppose to be 3 more; hence they will unite with the force of 6: the nature of this compound will be hereafter explained. Let us consider this to be the utmost force of attraction, that can subsist between oxygen and azote.

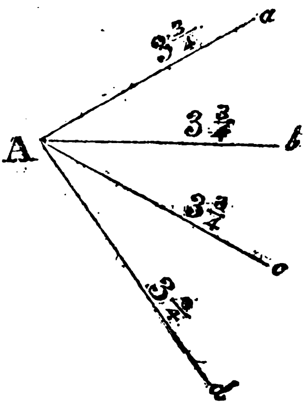


"We will now suppose a second particle of oxygen *b* to combine with A, they will only unite with the force of 4½; that is, the whole quantum of the attractive power of A, which is but 3, will be equally divided, and directed in two points towards *a* and *b*; so that A and *a b* will unite with the forces annexed to them in the diagram: *a* and *b* having no influence on each other, will suffer no diminution of their respective attractions for A. This I consider to be the real structure of a molecule of nitrous gas.

"Let a third particle of oxygen *c* unite to A, it will combine only with the force of 4. This is the state of the molecules of the red nitrous vapour, or, when condensed, the red nitrous acid. The diagram represents this molecule.*



“ We will suppose a fourth particle of oxygen *d* to combine with A; it will unite with the force of $3\frac{3}{4}$, and so on, with the rest of the particles of oxygen, as the diagram represents. This I consider to be the state of a molecule of the pale or straw-coloured nitrous acid.



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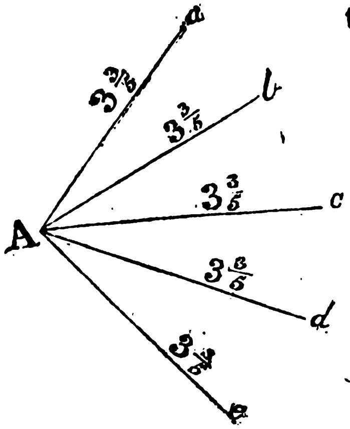
* Comp. View, page 134.

" When a fifth particle of oxygen *e* unites, the force of union existing between the particles of the molecule are still diminished, as is represented by the diagram. The fractions shew that the chemical attraction of azote for oxygen is nearly exhausted.



" This is the state of colourless nitrous acid;* and, in my opinion, no more oxygen can unite to the azote, having its whole force of attraction expended on the particles *a*, *b*, *c*, *d*, *e*.† This illustrates the nature of saturation, or *definite proportions*.

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[*] Since my book was written, this acid has been distinguished by the name *nitric acid*.

[†] Comp. View, page 135.

"We can readily perceive from the foregoing demonstrations, that oxygen is retained with less force in the colourless nitrous acid, than in the straw-coloured; and the latter acid retains it with less force than the red nitrous acid; and nitrous gas holds it still with more force than the red nitrous acid. This accounts for the separation of oxygen gas from the colourless nitrous acid, (nitric acid) when exposed to the sun, at the same time that the acid becomes coloured. Nitrous acid, in any other state, will afford no oxygen when exposed to the sun."*

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* Although oxygen can be separated from nitric acid very readily, and with little force, yet it would require the chemical power of about 16 to take the azote from its oxygen, so as to set the latter free in its gaseous state. We are not acquainted with any substance in nature, that has one third the force of this affinity to azote. The same law holds good with respect to carbonic acid and water, &c. No affinity to their inflammable base can set free their oxygen. This kind of separation is only effected by electricity and the de-oxydizing rays, or by the living power of growing vegetables, probably with the assistance of these imponderable elements.

The molecules, described above, being surrounded with atmospheres of caloric, are perfectly distinct and independent of each other, in their respective acids.

"The different acids will mix mechanically, in the following order, without disturbing or decomposing each other's molecules. 1. Red nitrous acid will mix with the pale, or straw-coloured, and the mixture acquires a light orange colour. 2. The pale mixes with the nitric, and imparts a slight shade of a yellow colour to it.*

"When the red nitrous acid is mixed with the nitric acid, the former takes one portion of oxygen from the latter, and the straw-coloured acid is produced; that is, new molecules, containing four particles of oxygen, are formed.

"Nitrous gas will not decompose the red acid, on the same principle that the latter will not decompose the pale; for the third particle of oxygen is retained by the acid molecules, with as great force as those of the gas attracts it. Nitrous gas will deprive the pale of one portion of its oxygen, and red nitrous acid is formed. Nitrous gas will also decompose the nitric, and a mixture of the molecules of the red and pale acids will be formed.

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* Comp. View, page 136.

"Having premised thus much on the different states of nitrous acid, I shall now proceed to its decomposition.

"If a metal be introduced into the red, pale, or colourless nitrous acid, it will be calcined, and nitrous gas will be extricated; that is, the metal will deprive the nitrous gas of the portion of oxygen necessary to the formation of the acid. The metal deprives the molecules of acid, within its immediate influence, of the whole of their oxygen. The force of 7, with which we have supposed metals to attract oxygen, being so much superior to $3\frac{3}{52}$, if we make use of the nitric, or $3\frac{3}{4}$, if we use the pale nitrous acid, together with the number of ultimate surfaces a metal must present, deprives the azote of its oxygen with such rapidity, that it is at once left destitute of both caloric and oxygen: but before it has time to collect an atmosphere of caloric, which would prevent a second union, it exerts the force of 3 on its neighbouring molecule of acid, which had not reached the metallic influence, and recovers that portion of oxygen necessary to the formation of nitrous gas. This again, in passing in the acid, if it be the pale or nitric acid, will receive sufficiency of oxygen to form red nitrous acid.* Hence it is, when first a metal is introduced into the pale or nitric acid, though solution goes on, that little or no nitrous gas is evolved until the acid becomes coloured. As the metallic oxide formed requires red nitrous acid to hold it in solution, (for nitric acid will not answer) the acid, which the azote deprives of a portion of oxygen, unites to it.

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* Comp. View, page 138.

" The foregoing demonstration may appear, at first sight, more fanciful than real. But does not the decomposition of nitre by metallic filings, whether they be deflagrated in a red hot crucible, or distilled by a gradual heat in a retort, tend to its confirmation? The acid is completely decomposed in this way, in whatever proportions the materials are used. In this case, the metallic particles deprive the nitrous molecules within their influence of the whole of their oxygen; and the azote, having no sensible attraction to the alkali, passes off in a gaseous state; for it cannot recover any oxygen from the molecules of nitre, in consequence of the united force of their azote and potash.

" I introduced iron filings into a mixture of about 1 of pale nitrous acid and 16 of water.* When they stood some time, azotic gas was produced, but no nitrous gas.[*] In this experiment, the few molecules of the nitrous acid, which come in contact with the metal, are deprived of the whole of their oxygen; and as the azote is liberated at a distance from the molecules of nitrous acid, and as its attraction is not sufficient to decompose water, it collects atmospheres of caloric, which defend it, in its passage through the solution, from the action of a portion of the oxygen of the suspended acid.

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* The objcet of this experiment was to prove the non-existence of hydrogen in metals. At the same time it helped to develope the atomic system.

"This experiment not only confirms the foregoing explanations of the decomposition of nitre and nitrous acid by metals, but also tends very much to overset the phlogistic theory. Here the metal is oxydized, and neither hydrogen nor nitrous gas is produced.[†]

"Let us add to this an experiment already described, viz. the solution of iron in sulphurous acid without the production of hydrogen; and the decomposition of it again by nitrous acid, without the formation of nitrous gas or azotic gas, although the metal is calcined and held in solution.

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[*] Comp. View, p. 140.

[†] Ibid. p. 141.

Here follows an explanation on the principles of my theory, (the atomic).

"The sulphurous acid dissolves the iron, and of course it is reduced into ultimate particles. Nitrous acid, dropped into this solution, is diffused through it, and, from the quantity of water which must necessarily be present in the sulphite of iron and in the nitrous acid, the molecules of both substances are in a great measure removed from each other, so that a single ultimate particle of iron can meet only a single molecule of nitrous acid, which supplies it with oxygen of calcination and acid of solution. Thus it is that no nitrous gas is produced at the same time that the whole of the sulphurous acid is disengaged.*

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* Comp. View, page 142.

"The great number of ultimate particles, which are concentrated in so small a compass in metals, from the nature of their texture, is the principal cause of the decomposition of nitrous or nitric acid during their solution in them."

I shall pass over a great many facts which were adduced, in order to ascertain the relative quantities of oxygen contained in nitrous gas and in gaseous oxide, particularly as they are at present known to almost every chemical reader, and confine myself to the following extract:

"The method of obtaining gaseous oxide from the solution of metallic nitrates favours the foregoing notions;* for we cannot procure it from nitrous or nitric acid, until they are nearly saturated with a metal; and then, by introducing more of the same metal, or a different metal, we obtain this gas, instead of the nitrous gas.

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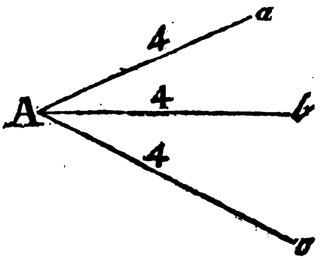
* That the atoms of the gaseous oxide consist of a single particle of azote and one of oxygen.

"To understand the rationale of this fact, we must consider, that the nitrous acid, which holds the metallic oxide in solution, is in the state of the red nitrous acid. Therefore, although the newly introduced metal deprives the acid of solution in contact with it, of the whole of its oxygen, yet the particles of azote recover a portion of it from their neighbouring molecules of acid, on principles which have been already explained.*

"The following demonstration will render this play of affinity sufficiently clear.



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* Comp. View, p. 170.

"Let the diagram represent the molecules of the acid of solution; if a metal be introduced into such a solution, it will deprive A of the whole of its oxygen; A being in contact with another molecule of acid of solution, will instantly seize on *a*, or *b*, or *c*, so as to constitute the gaseous oxide, and another particle of azote will at the same moment unite to a second particle of oxygen; thus the oxygen of the molecule of acid is expended in forming three portions of the gaseous oxide, while the metals are thrown down in the state of oxides.*

"It might be supposed, that a metal, when introduced into the red nitrous acid, in its simple state, should, on the foregoing principle, produce gaseous oxide. But we are to take into account that, although a particle of azote can only take one particle of oxygen from a single molecule of acid, another molecule in its vicinity will supply it with a second particle of oxygen, so as to constitute nitrous gas. This cannot happen in the metallic solution; for, when once the atom of gaseous oxide is formed, its attraction for more oxygen is not sufficient to take any of it from the united influence of the azote of the acid molecule and the particle of metal attached to it." *

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* It has already been shewn, by means of a diagram, that the atoms of gaseous oxide consist of a single particle of azote and one of oxygen, united with the force of 6. Sir Humphry Davy gave a very minute account of the nature and properties of this gas, in a work which he published in the year 1800.

The most ready way of obtaining the gaseous oxide is, by exposing nitrate of ammonia to heat in a pneumatic apparatus. This mode of procuring it was known when I wrote my Comparative View; but it was not immediately connected with the new philosophy, which I advanced.

" Having endeavoured to shew the nature of nitrous gas and nitrous oxide, so far as relates to the proportions of their respective elements, we can readily ac-

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† Comp. View, pages 171-2.

count, to a degree of certainty, why these gases do not affect each other when they are mixed; for the molecule of the nitrous gas retains its two particles of oxygen with as much force as the atom of the gaseous oxide can attract either of them.

This neutrality of the two gases, when mixed, is demonstrated by means of diagrams in the original work.

" Why the gaseous oxide should be more soluble in water than the nitrous gas, is what I cannot account for, unless it be occasioned by the smaller size of its calorific atmospheres, which may admit its atoms to come within the gravitating influence of that fluid.

" It is somewhat strange that the gaseous oxide should support combustion, while the nitrous gas, which contains more oxygen, has the reverse effect. It is also very singular, that nitrous gas will unite to more oxygen in a common temperature, and that the gaseous oxide will not, although it must have greater affinity to oxygen, as containing less of it than the former gas.

"That the red nitrous vapour, which contains much more oxygen, with less force, than the former gases, should not favour combustion, is still more singular.* Again, why Homberg's pyrophorus will burn in nitrous gas, and not in the gaseous oxide, is a fact which we cannot account for, unless it be occasioned by a larger supply of moisture in the former gas.†

"When we consider that neither carbonated hydrogen, nor hydrogen, nor azotic gases, will unite to oxygen gas, notwithstanding their great attraction to it, without the aid of the electric or a common spark; and compare these facts with the ease, with which oxygen gas and nitrous gas unite; we are led to attribute them to something, which surrounds their gravitating particles, and this we must suppose to be caloric, partly, as it is disengaged during their chemical union or condensation.

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* This is not the case: but it was thought proper not to make any alteration in the extract.

† Comp. View, page 173-4.

"But why caloric should not exert this power, when nitrous gas and oxygen gas are mixed together, is rather extraordinary; more especially when we know, as I have shewn upon a former occasion, that the calorific atmospheres of nitrous gas are much larger than those of azotic gas; and also, when we have every reason to suppose, that nitrous gas contains nearly all the caloric, which its component particles of oxygen and azote contained in their simple gaseous state.

"It is true that caloric is not given out by the union of nitrous gas and oxygen gas, which might favour their combination by a predisposing affinity of the acid molecule for the whole of the caloric of its constituents. This mode of reasoning, however, is not sufficient to account for the fact. The question is, how do their extensive atmospheres blend, so as to suffer their respective gravitating particles and molecules to approach within the reach of each other's chemical influence? The condensation of oxygen gas by nitrous gas, without the evolution of caloric, is a very striking fact.*

"That nitric acid contains nearly as much caloric as its constituent principles held before their union, can scarcely be questioned; and that it parts with very little caloric, on uniting to alkalies, is well known. Therefore, nitrate of potash contains, in its solid state, caloric sufficient to preserve the elasticity of, at least, 100 times its bulk of oxygen gas.

"Hence arise the deflagration of carbon and nitre in close vessels, and the quantity of caloric which is liberated, although carbonic acid gas is copiously evolved at the same time.

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* "Heat is produced, but not more than should be expected from the re-action of the newly formed acid upon the suspended water of the gases."

"These facts must convince us, that caloric unites chemically to bodies, and consequently that it gravitates towards them. Can we therefore doubt that caloric is a substance, and not a quality, as some philosophers are pleased to suppose?"

As chemists differ from each other respecting the proportions of the volumes of oxygen and azotic gases, which nitrous gas and gaseous oxide contain, I repeated the following experiments, which were formerly made by myself and others.

Ten measures of pure nitrous gas were charged into a glass jar, previously filled with quicksilver: some well-prepared pyrophorus was then sent up, which instantly inflamed, and reduced the gas. The residuary gas was passed into a graduated measure, where the reduction appeared to be only $\frac{4}{10}$. When the experiment was made with a larger quantity of pyrophorus, the 10 measures were reduced to 5½, and the residuary gas was found to be azote. Two trials more gave the same result.

The pyrophorus was sent up in a small glass tube open at both ends, one of which was closed by means of a cork, and it was perfectly filled with the pyrophorus: when passed under the jar, which contained the gas, the cork was withdrawn, and the tube, with its contents, was suffered to ascend. The whole of the pyrophorus, by agitating the jar, was readily exposed to the gas. From the inflammability of the pyrophorus, no time could be gained to press it into the tube; it was therefore only quickly filled, and immediately covered, and passed up. Hence it occurred to me, that some atmospheric air might have been mixed with it. To ascertain whether this was the case, the measure was filled with powdered charcoal, and passed up in the jar, which was filled with quicksilver. In this way half a measure of gas was produced.

My assistant, Mr. Wharmby, repeated these experiments over and over again, with the same result. Suspecting that the residuary gas contained carbonic gas, it was exposed to lime water; but no precipitation whatever appeared, and the gas was in no sensible degree diminished. When a lighted taper was plunged in it, the ignition instantly ceased, and oxygen gas had no effect on it.

We may infer from the foregoing facts, that a given measure of nitrous gas contains equal volumes of its constituent gases. The weight of 100 cubic inches of oxygen gas is 34 grains, and that of the same volume of azotic gas about 30 grains; therefore, the weight of the molecule of nitrous gas must be the multiple of the weight of its constituent particles; and, if the two gases were condensed by their chemical union to the dimensions of either of them, 100 cubic inches of nitrous gas should weigh 64 grains, whereas they weigh but 37. Therefore, the calorific atmospheres of the molecules of this gas are twice larger than those of either of its constituent gases.

I exposed potassium to dry nitrous gas over mercury, and no change whatever was produced in either of them, although they were suffered to stand until the potassium was absorbed by the mercury, which had taken three days. When water was thrown up, hydrogen was given out by the amalgam.

A small quantity of potassium was passed into a jar, containing $6\frac{1}{2}$ measures of nitrous gas, and a quantity of water, barely sufficient to ignite it, was sent up; as soon as they came in contact, a sudden flash was produced, accompanied with a concussion of the apparatus, and the gas was reduced to five measures, which consisted of hydrogen, azote, and nitrous gas.

When a larger proportion of potassium was used, ten measures were reduced to six, which contained azote in a free state, hydrogen, and nitrous gas. The rapidity, with which nitrous gas is decomposed in this way, can only be equalled by the firing of oxygen and hydrogen, or oxygen and any other inflammable gas, by the electric spark.

The experiments with potassium were made, with a view to ascertain the effects of this new metal on the gas; for I was perfectly satisfied with its analysis by means of the pyrophorus.

The various ways of decomposing this gas by moistened iron filings, and by sulphuretted hydrogen, were repeated for the first time (by me) since I wrote my "Comparative View," and I observed nothing particular, except in one experiment, when equal parts of sulphuretted hydrogen and nitrous gas, which stood separately over dry mercury for several days, were mixed, no decomposition took place, although the mixture was suffered to stand for three weeks. When water was sent up, the whole of the gases, except a large bubble of azote, disappeared in the course of seven days. The water contained no free acid nor ammonia, and, when filtered and evaporated to dryness in a gentle heat, a small quantity of nitrate of ammonia was left.

By repeated trials I could never succeed in this experiment, but when the gases and mercury, which confined them, were perfectly dry. This curious fact has escaped the observation of chemists.

The following experiments were made to ascertain the proportion of the constituents of gaseous oxide.* 43 measures of hydrogen and 46 of gaseous oxide were fired in a glass jar, over mercury, by the electric spark: the residuary gas was of the standard of atmospheric air. 3 measures of gaseous oxide, and 4 of hydrogen, when fired, were reduced to nearly 4 measures, which consisted of azote and hydrogen. When equal volumes of the gases were fired, the mixture was reduced to one half. This residuum was not diminished by water, and when a lighted taper was plunged into it, the ignition instantly ceased; therefore we have every reason to suppose that it was azote. These experiments were repeated with the same result.

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* Similar experiments were made by Sir Humphry Davy, in the year 1800.—*See his Researches.*

The foregoing experiments on nitrous gas and gaseous oxide shew, that the former contains equal bulk of oxygen gas and azotic gas, and that the latter consists of one measure of azotic and half a measure of oxygen gases condensed into the volume of one measure. The nitrous gas is found as much expanded as its constituent gases would have been, were they only mechanically mixed; so that little or no diminution of their volume is produced by their chemical union. This accounts for the greater specific gravity of the gaseous oxide; and this difference in their weights must depend on the size of their respective atmospheres of caloric.

The principal question is, in what proportion of their ultimate particles do their respective atoms or molecules exist? The estimate which I formerly gave, when I first introduced the atomic system, as may be seen in some of the foregoing pages, is, that a molecule of nitrous gas consists of a single ultimate particle of azote and two of oxygen, and that an atom of gaseous oxide contains one of azote and one of oxygen.

Mr. Dalton and most chemists suppose that the atoms of nitrous gas consist of one ultimate particle of azote and one of oxygen, and those of nitrous oxide of two of azote and one of oxygen. The quantity of the simple gases, which are necessary to constitute these compounds, I must own, favours this estimate. However, I do not see any reason why I should relinquish my former opinion.

The specific gravity of oxygen gas is very little more than that of azotic, and this I attribute to the dimensions of their respective atmospheres of caloric, those of the latter gas being more extensive and less dense.

In my opinion, the ultimate particles of azote are larger, and of course heavier, than those of oxygen. I also conceive that a measure of oxygen gas contains twice the number of ultimate particles, that are contained in the same volume of azotic gas.

Indeed, the great number of particles of oxygen, which a single particle of azote is capable of uniting to and governing, for instance, in nitric acid, justifies in a great measure this hypothesis.

According to the philosophy which I laid down in my "Comparative View," and which I have proved to be correct in most instances, an ultimate particle of an inflammable base is capable of uniting to 1, 2, 3, 4, or more of the particles of oxygen, according to the nature of the inflammable substance; while, on the other hand, a single particle of oxygen, as I mentioned on a former occasion, cannot unite to more than one particle of any inflammable matter. To suppose the contrary, would be reversing that delightful symmetry, which nature uniformly presents to our view on every occasion.

Besides, were a particle of oxygen capable of uniting to 2 or 3, or more particles of inflammable base, there would be no end to compounds and monstrous compounds, which never occur in chemical investigations.

The chemical action of the muriatic acid on metals was explained on the atomic principle, and demonstrated by diagrams, somewhat like those which I have already adduced on the subjects of sulphuric and nitrous acids.* When I wrote, oxymuriatic acid was supposed by the phlogistians to be muriatic acid, deprived of phlogiston or hydrogen. This was also the opinion of Scheele, who first discovered this singular substance. Berthollet, I believe, was the first who considered oxymuriatic acid to be a compound of muriatic acid and oxygen. Some of the experiments and demonstrations, which I brought forward at that time, appeared very favourable to Berthollet's hypothesis, as the following extract will shew.

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* Comp. View, page 190—3.

"When muriatic and nitric acids are mixed, nitrous gas is produced. This, however, depends upon proportions. If they are mixed in the proportions of two of the nitric to three of the muriatic, provided the acids are strong, nitrous gas is evolved, and the mixture becomes very hot. When it cools, the nitrous gas ceases to come over, and numerous bubbles are generated in different parts of the acid, which are absorbed almost as soon as they are formed. They sometimes appear at the bottom of the liquor, and pass upwards in slender streams, rapidly diminishing in their progress until they can no longer be traced. This phenomenon is attended with a hissing noise, which must be occasioned by absorption. I endeavoured, but without success, to obtain some of this gas.

"Thus we find, that muriatic acid will take oxygen from the nitric with as great facility as from the oxide of manganese, and that it acts on this acid in a similar manner as it does on the metals, by withdrawing oxygen from it, and not, as the phlogistians imagine, by imparting phlogiston to it. . . . .

"It is well known that nitrous gas will not form nitrous acid without the addition of oxygen. Yet Pelletier produced nitrous acid and muriatic acid, by mixing oxymuriatic gas and nitrous gas.[*] This is a convincing proof of the existence of oxygen in oxymuriatic acid.[†]. . . . . .

I considered muriatic acid at this period to consist of an unknown inflammable base

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[*] 26 Iroz. 393.

[†] Comp. View, p. 207.

and oxygen, and that they were united with the force of 6. This is considerably greater than the force, with which oxygen was supposed to be attached to its azotic base in nitric, pale, or red nitrous acids, as has been already mentioned.

" Stating the comparative forces, with which oxygen is retained in those acids rather than their absolute forces, which cannot be ascertained, we shall be the more enabled to account for the following facts. Pelletier has observed, that nitric acid is completely decomposed, when added in a small proportion to muriatic acid, and that its azote is disengaged in a gaseous state, although azote attracts the quantity of oxygen necessary to the formation of nitrous gas with greater force than the muriatic acid.

" The foregoing fact is only explicable on the following principles. When a small portion of nitric acid is diffused in a large quantity of muriatic, the latter exposes surfaces sufficient to separate, with one uniform or co-operating influence, the whole of its oxygen from the azote.* For the force of 4, on the side of the muriatic molecules, is sufficient to overcome, if the nitric acid be used, the force of $3\frac{3}{5}$, or, should it be the pale acid, the force of $3\frac{3}{4}$. Red nitrous acid, in its pure state, will not be decomposed; for it retains its oxygen with as great force as the muriatic acid attracts it: therefore they will form a kind of union without decomposition.

"When a larger quantity of nitric acid is mixed with the muriatic acid, nitrous gas is produced; for, as a molecule of the muriatic can only deprive a single molecule of nitric acid, at most, but of two ultimate particles of oxygen, there are not a sufficient number of the former within the reach of the latter to effect a total decomposition, that is, a separation of the whole of its oxygen from the azote; for such a decomposition cannot take place, but by the simultaneous influence, at the same instant, of different molecules of muriatic, while the nitric molecule is perfect. Thus it is that nitrous gas is formed, and as it retains its oxygen with greater force than nitric acid, it passes off through the muriatic acid in its gaseous state. *Muriatic gas and nitrous gas, when mixed over mercury, have no action whatever on each other.*

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* Comp. View, page 210.

"It appears to me, that oxymuriatic gas retains its oxygen with as great force, nearly, as nitrous gas; for, when these gases are perfectly dry, and mixed over mercury, no decomposition takes place until water is introduced. Hence I infer that water assists in the decomposition, from its attraction to muriatic acid."*

While writing these pages, I made the following experiments.

Fused muriate of lime was introduced into a small glass globe, which, when exhausted as much as possible, by means of a good air pump, was filled with oxymuriatic gas: it was a second time exhausted, and this process was repeated three times, which induced me to suppose that the whole of the atmospheric air was pumped out: it was then filled with oxymuriatic gas. A glass jar was filled with nitrous gas over quicksilver; and both gases were suffered to rest in contact with muriate of lime for forty-eight hours. When a communication was formed, by means of stop cocks, the two gases exchanged situations with each other in a few minutes. The nitrous gas, being the lighter, ascended at the same time that the oxymuriatic gas descended, and occupied its place in the jar. The globe exhibited a red appearance, which proved that nitrous vapour was formed. On standing for some time, the gases and nitrous vapour mixed with each other, and the surface of the quicksilver was much corroded.

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* Comp. View, p. 211-2.

When a portion of the gas in the jar was passed into a glass tube, and agitated in contact with quicksilver, until the whole of the oxymuriatic gas was condensed, water produced no diminution in the residuary gas, which was found to consist of nitrous and azotic gases. As no muriatic gas was formed, no interchange of elementary principles took place between the oxymuriatic gas, the nitrous gas, and water. The red colour, produced by the nitrous gas, must proceed from some atmospheric air, which remained in the receiver, notwithstanding the pains taken to get rid of it.

The result of the foregoing experiment induced me to make the following:

Oxymuriatic gas was quickly passed into a glass jar, half filled with dry nitrous gas over mercury: no apparent change took place: and when water was introduced, the oxymuriatic gas was condensed, and the nitrous gas remained unaltered; for the whole of it was converted into red nitrous vapour by oxygen gas. As soon as this vapour was absorbed by the water, it acted on the quicksilver, and a slight degree of effervescence ensued: this was occasioned by the reproduction of nitrous gas, which gradually condensed a small residuum of oxygen remaining in the jar.

This experiment proves that oxymuriatic gas and nitrous gas do not decompose each other, and that no affinity exists between them, and also that red nitrous vapour has little or no action on oxymuriatic acid.

These facts, together with many others, adduced by Sir Humphry Davy, tend to shew, that oxymuriatic gas does not contain oxygen so loosely combined as has been heretofore imagined; and the probability is, that it contains no oxygen. This, however, remains to be proved.

Having repeated experiments, which I formerly made, I shall drop the subject at present, particularly as it does not immediately relate to the object of this essay.

I will pass over different sections, which treat on the oxydation of metals in different ways; on their reduction again to their metallic state; and on the solubility of metals in acids.

Those different processes were strictly and impartially enquired into, on the principles of both antagonist doctrines, at this period; and, assisted by the atomic system, I was able to draw fairer and juster conclusions than I otherwise could.

In the section which relates to the precipitation of metals by each other, from their solution in acids, the structure of the compound molecules of the metallic salt is represented by diagrams; and the relative forces, with which their elementary particles influence each other, is expressed by numbers. The following extract will give one example of this kind, which will be sufficient.

" A neutral solution of sulphate of copper consists of an oxide of copper and sulphurous acid, chemically united. The sulphurous acid is less intimately attached to the copper than the oxygen. Iron will throw down the copper in this solution, in its metallic state, by taking from it the acid and the whole of its oxygen, with one sudden and uniform effort.

" To account for this decomposition, it is necessary to have recourse to the following illustration.*

" C in the diagram represents a particle of copper, O oxygen, which, we will suppose, attract each other with the force of $2\frac{2}{3}$; to avoid perplexity, reciprocal attraction is not considered. Let S, which represents sulphurous acid, be united to this oxide with the force of 3; and let us suppose 2 of this force to proceed from the oxygen attached to the copper, and the remainder, which is but 1, to be occasioned by the influence of the copper itself on the sulphur and oxygen of the sulphurous acid; therefore let G designate the centre of gravity of S.

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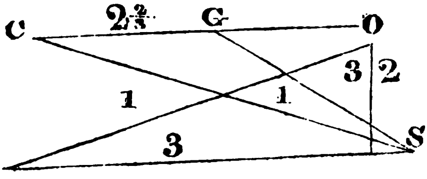
* Comp. View, p. 262.



" Let us now suppose this to be the state of a molecule of sulphate of copper: here the copper attracts S and O with only the force of $3\frac{2}{3}$; and C and O conjointly influence S with the force of 3. Let us again suppose I, which represents, in the diagram, a particle of iron, to attract S, or sulphurous acid, with the force of 3; it cannot take it from C and O, which hold it with the force of 3; but it so counteracts the attachment of O and S to C, as to reduce it to $\frac{2}{3}$. Let us suppose I, from its attraction to oxygen, to influence O with the force of 1 more: in this case, C will be deprived of O and S;

for the force of $3\frac{2}{3}$ must yield to the power of 4.*

"Should the iron unite first to the sulphurous acid, the resulting compound would have no action on the oxide; for the sulphite of iron does not take any of its oxygen from the oxide of copper, when both are mixed. Hence it appears, as observed above, that the whole force of the iron, in order to throw down the copper in its metallic state, must be exerted at the same instant towards S and O conjointly.†

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* Comp. View, page 263.

† A molecule of sulphate of copper contains as much oxygen as that of sulphate of iron; it is composed of 1 particle of copper, 1 of sulphur, and 3 of oxygen, attached to each other in such a way as to consist of two compounds, viz. an oxide and sulphurous acid.

When potash is introduced into a solution of this sulphate, it takes from it the acid of solution, with the full portion of oxygen necessary to constitute sulphuric acid. Therefore a molecule of sulphate of potash consists of the oxide of potassium and sulphuric acid, intimately united;

"All metallic precipitations are effected on the foregoing principles. Should the precipitant be unable to take up the whole of the oxygen of the precipitated metal, it falls down in the state of a semi-oxide. Thus lead and silver will precipitate gold from its solution of a dull purple colour, while copper and iron throw it down in its metallic state."

The precipitation of one metal by another from its solution in an acid, in the state of an oxide, was, at this distant period, urged

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or of the following proportion of its constituent elements, 1 particle of potassium, 1 of sulphur, and 3 of oxygen. A molecule of sulphite of iron consists of a particle of the metal, united to an atom of sulphurous acid. Sulphite of potash contains one third less oxygen than its sulphate.

When the metallic oxides and sulphur are mixed, and exposed to sufficient heat, sulphurous acid is formed. When the alkaline or earthy oxides are treated in the same manner, no decomposition is effected; the sulphur unites to them, and forms as perfect a sulphuret as if there had been no oxygen present: this is owing to the strong affinity of the metallic bases to their oxygen.

as unfavourable to the anti-phlogistic doctrine, particularly by Mr. Kirwan in his Essay on Phlogiston. The answer, which I made on this occasion, shall terminate this essay.

" Mr. Kirwan's fourth query is very much in favour of the anti-phlogistic doctrine; for, as I observed on a former occasion, the precipitation of one metal by another, in the state of an oxide, without the evolution of hydrogen, at the same time that the precipitant is held in solution, is a strong proof of the non-existence of that principle in metals: besides, the fact is very explicable by the anti-phlogistic theory.*

" I have already shewn, upon what principle the different inflammable bases retain their oxygen with less force, when perfectly saturated with it, than when united to smaller proportions; and I have also shewn, in treating on nitrous and nitric acids, that the force of union of their base to oxygen is inversely to the quantity of oxygen, with which it is united.

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* Comp. View, page 274.

" The same law holds good in all kinds of chemical combinations, and is explicable on the same principles. Almost all bodies, particularly elementary bodies, will unite to the different substances, to which they have an affinity, in various proportions, according to their nature, until they arrive at the point of saturation, which limits the power of chemical attraction.

" There are some exceptions to this law; for the principles of water will only unite in one proportion, so that we never have obtained them in an intermediate state of combination. I have some doubts whether the same observation might not be applied to the carbonic acid.

" Metals unite to oxygen in various proportions, until they are saturated. If

100 grains of a metal are only capable of uniting to 15 grains of oxygen, they will attract and retain 5 grains of oxygen with greater force than they will 10 grains, and 10 grains with greater force than 15 grains.*

" Suppose 100 grains of tin, when in perfect solution in an acid, should be united to 15 grains of oxygen with the force of $5\frac{1}{2}$, and that iron should attract oxygen with the force of 7, and let us suppose this force to be reduced to 6, by the accession of $7\frac{1}{2}$ grains of oxygen, and the force of the attraction of the tin to the remainder of its oxygen to increase by this loss: under these circumstances, iron could not precipitate tin in its metallic state, although it may have greater attraction to the oxygen and acid of solution than the tin has. Hence it is evident, that a metal, in order to throw down another in its pure metallic state, must not only unite to oxygen in greater quantities, and attract it more forcibly, but that this superiority of force must be very considerable."

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* Comp. View, pages 275-6.

Having produced a number of facts, taken from the philosophy, which I advanced many years before the close of the last century, I will now lay before the reader a sample of Mr. Dalton's "*New System of Philosophy*," published in the eighth year of the present century. I have fixed, according to my judgment, on the very best part of his work, so far as relates to the atomic doctrine. It will be found very nearly the ditto of the principles which I established, excepting his omission of numbers, which represent the relative force of the chemical attraction of particles and atoms to each other, and which appears to me to be one of the most important features of my system.

Here follows Mr. Dalton's third chapter, on chemical synthesis.

"ON CHEMICAL SYNTHESIS.*

"When any body exists in the elastic state, its ultimate particles are separated from each other to a much greater distance than in any other state; each particle occupies the center of a comparatively large sphere, and supports its dignity by keeping all the rest, which, by their gravity, or otherwise, are disposed to encroach upon it, at a respectful distance. When we attempt to conceive the *number* of particles in an atmosphere, it is somewhat like attempting to conceive the number of stars in the universe; we are confounded with the thought. But if we limit the subject, by taking a given volume of any gas, we seem persuaded that, let the divisions be ever so minute, the number of particles must be finite; just as in a given space of the universe the number of stars and planets cannot be infinite.

"Chemical analysis and synthesis go no farther than to the separation of particles one from another, and to their re-union. No new creation or destruction of matter is within the reach of chemical agency. We might as well attempt to introduce a new planet into the solar system, or to annihilate one already in existence, as to create or destroy a particle of hydrogen. All the changes we can produce, consist in separating particles that are in a state of cohesion or combination, and joining those that were previously at a distance.

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* New System of Chemical Philosophy, p. 211.

" In all chemical combinations, it has justly been considered an important object to ascertain the relative *weights* of the simples, which constitute a compound. But unfortunately the enquiry has terminated here; whereas from the relative weights in the mass the relative weights of the ultimate particles or atoms of the bodies might have been inferred, from which their number and weight in various other compounds would appear, in order to assist and guide future investigations, and to correct their results. Now it is one great object of this work, to shew the importance and advantage of ascertaining *the relative weights of the ultimate particles, both of simple and compound bodies, the number of simple elementary particles which constitute one compound particle, and the number of less compound particles which enter into the formation of one more compound particle.*

" If there are two bodies, A and B, which are disposed to combine, the following is the order in which the combinations may take place, beginning with the most simple; namely,

1 atom of A + 1 atom of B = 1 atom of C, binary.
1 atom of A + 2 atoms of B = 1 atom of D, ternary.
2 atoms of A + 1 atom of B = 1 atom of E, ternary.
1 atom of A + 3 atoms of B = 1 atom of F, quaternary.
3 atoms of A + 1 atom of B = 1 atom of G, quaternary.
&c. &c.

" The following general rules may be adopted as guides in all our investigations respecting chemical synthesis.

1st. When only one combination of two bodies can be obtained, it must be presumed to be a *binary* one, unless some cause appear to the contrary.

2d. When two combinations are observed, they must be presumed to be a *binary* and a *ternary*.

3d. When three combinations are obtained, we may expect one to be a *binary*, and the other two *ternary*.

4th. When four combinations are observed, we should expect one *binary*, two *ternary*, and one *quaternary*, &c.

5th. A *binary* compound should always be specifically heavier than the mere mixture of its two ingredients.

6th. A *ternary* compound should be specifically heavier than the mixture of a binary and a simple, which would, if combined, constitute it, &c.

7th. The above rules and observations equally apply, when two bodies, such as C and D; D and E, &c. are combined.*

" From the application of these rules, to the chemical facts already well ascertained, we deduce the following conclusions; 1st. That water is a binary compound of hydrogen and oxygen, and the relative weights of the two elementary atoms are as 1:7, nearly; 2d. That ammonia is a binary compound of hydrogen and azote, and the relative weights of the two atoms are as 1·5, nearly: 3d. That nitrous gas is a binary compound of azote and oxygen, the atoms of which weigh 5 and 7 respectively; that nitric acid is a binary or ternary compound, according as it is derived, and consists of one atom of azote and two of oxygen, together weighing 19; that nitrous oxide is a compound similar to nitric acid, and consists of one atom of oxygen and two of azote, weighing 17; that nitrous acid is a binary compound of nitric acid and nitrous gas, weighing 31; that oxynitric acid is a binary compound of nitric acid and oxygen, weighing 26; 4th. That carbonic oxide is a binary compound, consisting of one atom of charcoal and one of oxygen, together weighing nearly 12; that carbonic acid is a ternary compound; (but sometimes binary) consisting of one atom of charcoal, and two of oxygen, weighing 19; &c. &c. In all these cases the weights are expressed in atoms of hydrogen, each of which is denoted by unity.

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* The terms, *binary*, *ternary*, *quaternary*, &c. were introduced long before Mr. Dalton had written; and in the same sense.

" In the sequel the facts and experiments, from which these conclusions are derived, will be detailed; as well as a great variety of others from which are inferred the constitution and weight of the ultimate particles of the principal acids, the alkalies, the earths, the metals, the metallic oxides and sulphurets, the long train of neutral salts, and in short all the chemical compounds which have hitherto obtained a tolerably good analysis. Several of the conclusions will be supported by original experiments.

" From the *novelty* as well as importance of the ideas suggested in this chapter, it is deemed expedient to give plates, exhibiting the mode of combination in some of the more simple cases. A specimen of these accompanies this first part. The elements or atoms of such bodies, as are conceived at present to be simple, are denoted by a small circle, with some distinctive mark; and the combinations consist in the juxta-position of two or more of these; when three or more particles of elastic fluids are combined together in one, it is to be supposed that the particles of the same kind repel each other, and therefore take their stations accordingly.

" EXPLANATION OF THE PLATE.

" This plate contains the arbitrary marks, or signs, chosen to represent the several chemical elements, or ultimate particles.

Fig.			Fig.		
1	Hydrogen, its rel. weight	1	11	Strontites	46
2	Azote	2	12	Barytes	68
3	Carbon, or charcoal	3	13	Iron	38
4	Oxygen	7	14	Zinc	56
5	Phosphorus	9	15	Copper	56
6	Sulphur	13	16	Lead	95
7	Magnesia	20	17	Silver	100
8	Lime	23	18	Platina	100
9	Soda	28	19	Gold	140
10	Potash	42	20	Mercury	167

21. An atom of water, or steam, composed of 1 of oxygen and 1 of hydrogen, retained in physical contact by a strong affinity, and supposed to be surrounded by a common atmosphere of heat; its relative weight = - - - - - - - - 8

22. An atom of ammonia, composed of 1 of azote and 1 of hydrogen - - - - - - - - - - - 6

23. An atom of nitrous gas, composed of 1 of azote and 1 of oxygen - - - - - - - - - - 12

24. An atom of olefiant gas, composed of 1 of carbon and 1 of hydrogen - - - - - - - - - 6

25. An atom of carbonic oxide, composed of 1 of carbon and 1 of oxygen - - - - - - - - 12

26. An atom of nitrous oxide, 2 azote + 1 oxygen - 17

27. An atom of nitric acid, 1 azote + 2 oxygen - - 19

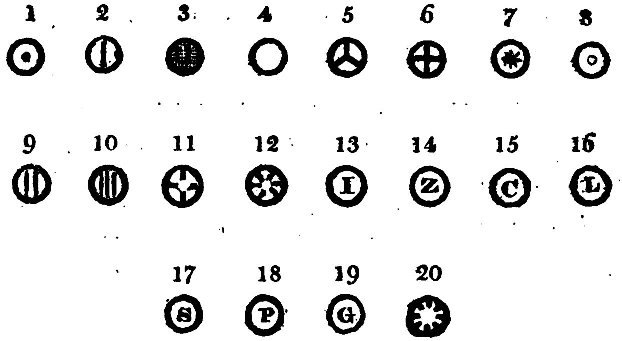
28. An atom of carbonic acid, 1 carbon + 2 oxygen 19

29. An atom of carburetted hydrogen, 1 carbon + 2 hydrogen - - - - - - - - - - - - 7

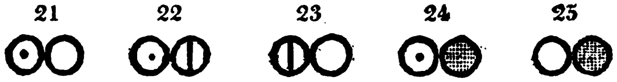
(FAC-SIMILE OF PLATE.)

ELEMENTS.

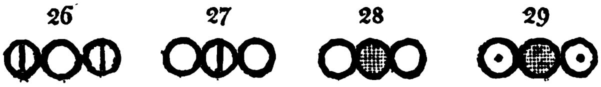
SIMPLE.



BINARY.



TERNARY.



The respect which I feel for truth and justice, rather than ambition for fame, induced me to undertake this task. The grateful acknowledgment of the public is all the reward men of science expect; and should they be liable to be stripped of that feather, through flippancy and manœuvre, the grand object must be frustrated; men of true science will quit the field in disgust; and many will be deterred from entering into it, to the great injury of the science.

APPENDIX.

SINCE writing the foregoing pages, an extract, taken from a very ingenious essay on the cause of chemical proportions, written by Berzelius, Professor of Chemistry at Stockholm, appeared in a periodical work, called "Annals of Philosophy, &c." (for December, 1813) of which Dr. Thomson, it seems, is the editor. The celebrated author of this essay makes the following remarks on the atomic system.

. . . . "When we reflect on this cause, it is first evident that it must be of a mechanical nature; and what presents itself as the most probable idea, most conformable to our experience, is, that bodies are composed of atoms or of molecules, which combine 1 with 1, 1 with 2, or 3, 4, &c. and the laws of chemical proportions seem to result from this with such clearness and evidence, that it seems very singular that an idea, so simple and probable, has not only not been adopted, but not even proposed, before our own days.

"As far as I know, the English philosopher, Mr. John Dalton, guided by the experiments of Bergman, Richter, Wenzel, Berthollet, Proust, and others, was the first person who endeavoured to establish that hypothesis.

"Sir Humphry Davy has lately assured us that Mr. Higgins, in a book, published in 1789, established the same hypothesis. I have not seen the work of Mr. Higgins, and can only notice the circumstance on the authority of Davy."

Here follows Dr. Thomson's remarks on this passage, in a note at the foot of the page.

"The work of Higgins on *phlogiston* is certainly possessed of much merit; and anticipated some of the most striking subsequent discoveries. But when he wrote, metallic oxides were so little known, and so few exact analyses existed, that it was not possible to be acquainted with the grand fact that oxygen, &c. always unite in determinate proportions, which are multiples of the minimum proportion. The atomic theory was taught by Bergman, Cullen, Black, &c. just as far as it was by Higgins. The latter, indeed, states some striking facts respecting the gases, and anticipated Gay Lussac's theory of volumes; but Mr. Dalton first generalized the doctrine, and thought of determining the weight of atoms of bodies. He shewed me his table of symbols, and the weight of the atoms of six or eight bodies, in 1804; and I believe the same year explained the subject in London, in a course of lectures delivered in the Royal Institution. The subject could scarcely be broached sooner. But about the same time several other persons had been struck with the numbers in my table of metallic oxides, published in my Chemistry; and the doctrine would have certainly been started by others, if Dalton had missed it. "T."

If Dr. Thomson thought so much of my work on phlogiston, as he, erroneously, is pleased to call it, why not take notice of it in his Chemistry? As a compiler, he should not have passed it over.

This curious note of his accounts for the omission. He wished to leave the work itself in undisturbed oblivion; but whatever was valuable in it, he generously chose to bestow on Mr. Dalton.

"*When he wrote, metallic oxides, &c.*"

When I wrote, I was as well acquainted with metallic oxides as I am this present moment.* And I was the first that established "*the grand fact, that oxygen, &c. always unite in determinate proportions, which are multiples of the minimum proportion,*" as almost every page of this essay, which relates to the subject, will prove.

"*The atomic theory was taught by Bergman, Cullen, Black, &c.*"

I have read the works of those chemists repeatedly, and I have not met with a single page, that relates to the atomic theory. Were these philosophers now in existence, they would shrink from the compliment with honest indignation.

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[*] See the following pages in this essay, viz. 70, 116-17, and 163; and in Comp. View, 229—30.

It is true, at the time I wrote, I thought the ultimate particles of most metals were capable of uniting to three particles of oxygen. I am now of opinion, that there are but two distinct oxides of any one metal, and that the mistake of modern writers arises from a mixture of those oxides in different proportions.

" *The latter, indeed, states some striking facts respecting the gases, and anticipated Gay Lussac's theory of volumes.*"

I have also attended to their particles, and to the relative weight of the particles and atoms of the different gases, as may be seen in many pages of this essay.

" *But Mr. Dalton first generalized the doctrine, &c.*"

The doctrine was as extensively applied by me, and, what is still more important, it was founded on well-chosen facts and mathematical demonstrations, which Dalton omitted for reasons best known to himself. In a word, it will be found that Dalton has not done justice to my doctrine, with all his ingenuity; and his attempt to weigh a few atoms, no matter how, or whether he is correct or not, gives him no claim whatever to the system, which I established several years before he or Dr. T. were known as chemical writers.

"*The subject could scarcely be broached sooner.*"

This and the remaining part of the Doctor's note exhibit such self-evident misrepresentations, that I need not say a single word on the subject, but refer the reader to the pages of this work. Indeed, I did not expect that such prejudice on the one side, and partiality on the other, should flow from the pen of so respectable a writer as Dr. Thomson.

The generous age of chemical science is no more. In my early days, it was my fortune to live at the same time, and to associate with, many of the venerable fathers of our present system. In that auspicious period, the ultimate and ardently expected object of research was truth: not the advancement of an individual's reputation. Philosophers were then eager to attribute the merit of discovery to its rightful owner, not to appropriate it to themselves or others. But now, in the vale of life, I am myself obliged to rescue the labours of my youth from the claims of those, who have adopted them without ceremony, and who have even attempted to force them from me by means of their combined exertions. However, justice will force its way sooner or later against all obstacles and prejudices. The subject is not, now, confined to the decision of a few individuals, but is laid before a grand tribunal, and it rests with them to give a verdict.

FINIS.

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